Learning Spatial Concepts through Experience

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Abstract

As they gain expertise in problem solving, people increasingly rely on patterns and spatially-oriented reasoning. This paper describes an associative visual pattern classifier and the automated acquisition of new, spatially-oriented reasoning agents that simulate such behavior. They are incorporated into a game-learning program whose architecture robustly combines agents with conflicting perspectives. When tested on three games, the visual pattern classifier learns meaningful patterns, and the pattern-based, spatially-oriented agents generalized from these patterns are generally correct. The accuracy of the contribution of each of the newly created agents to the decision-making process is measured against an expert opponent, and a perceptron-like algorithm is used to learn game-specific weights for these agents. Much of the knowledge encapsulated by the correct new agents was previously inexpressible in the program's representation and in some cases is not readily deducible from the rules.

Keywords: game playing, pattern recognition, concept formation, machine learning, spatially-oriented reasoning.

Pattern Learning in Game Playing

Humans use two kinds of pattern-oriented learning for game playing: they associate particular patterns with successful or unsuccessful play, and they construct spatially-oriented heuristics from those patterns. Figure 1(a), where the empty locations are blanks and # denotes "don't care," is an example of the association of an individual pattern with a particular outcome of the game. It links a particular pattern from tic-tac-toe with success for X. In any symmetric orientation and whatever the # squares contain, a human expert associates such a configuration with a win for X.

Along with particular patterns, game-playing experts use more general but equally salient heuristics as spatially-oriented "rules of thumb." Figure 1(b) is an example of such a pattern-based concept. It is the spatially-oriented heuristic "reflect O's move through the center," proved to be optimal play for X in the game of lose tic-tac-toe (Cohen 1972). Advice from experts on how to analyze and play games is repeatedly couched in the language of such spatially-oriented patterns. Chess and checkers are discussed in terms of controlling the center of the board, while control of the edges is crucial in Othello (Fine 1989; Gelfer 1991; Lee & Mahajan 1990; Samuel