Relating Perceptual and Functional Features for Game Learning

Shira Sand
(sbsand@princeton.edu)
Department of Electrical Engineering
Princeton University
Princeton, NJ 08544 USA

Jack J. Gelfand
(jjg@princeton.edu)
Department of Psychology
Princeton University
Princeton, NJ 08544 USA

Susan Epstein
(epstein@roz.hunter.cuny.edu)
Department of Computer Science
Hunter College, and The Graduate School, CUNY
New York, NY 10021 USA

The relationship between spatial features and decision making is readily evident in game playing. Often, the rules of a game provide a structure for thinking about the spatial relationships of the pieces on the board. For example, the rules for moving pieces are related to spatial features such as distance and contiguity. If we want to create a computer program that can learn the salient spatial features of a game playing task, we need to create a efficient concept formation language. This work examines the relationship between perceptual features and functional features in the creation of a spatial concept formation language.

Studies of human problem-solving suggest that perception receives both stimulus input from the sensory system and input from internal intentions and expectations (Rogers 1995). Rogers (1995) has suggested a cyclic system of interaction between the perceptual and problem-solving processes. Prior knowledge and functionally relevant features are known to influence concept formation (Wisniewski 1995). Olson and Bialystok (1983) define a spatial concept as consisting of two parts: a structural description, consisting of features and their relations, and meaning, representing the intentions, purposes, and goals of the perceiver. The meanings are represented independently of the structural description, but are the criteria in terms of which features are selected, detected, and added to the structural description.

In a learning program, a natural representation for a concept should reflect the reason for concept membership (Flann & Dietterich 1986). In game playing, although concepts are often naturally functional, recognition and performance tasks favor a structural representation. Wyl addresses this with a multiple representation strategy for chess and checkers (Flann & Dietterich 1986). Our approach differs from theirs because rather than converting between structural and functional descriptions, we integrate the two in forming a language to describe concepts where notions of space and function are closely linked.

We began with the general functional game playing concept of opportunity, i.e., access to as many states as possible that could lead to a win. Opportunity, as such, is not a spatial concept. Through a particular subgoal in a given game, this functional concept can generate spatial concepts. We focused on the defensive component of opportunity to make a mill in the game of five men's morris, where a mill is the explicit subgoal of obtaining three pieces in a row. Clustering boards from actual games, we developed two functional subclusters: those that guarantee the future ability to construct a mill, and those that offer a strong possibility to do so. Each subcluster constitutes a spatial concept generalized in terms of simple features: line, occupy, and own, based upon the vertices of the board. Boards with guaranteed mills possess a line with all three vertices owned by the player who can make the mill. Boards with a strong possibility of a mill have a line in which one player owns two vertices while the opponent owns none.

We used this approach to construct a new spatial decision-making module in Hoyle, a hierarchical mixture of experts game-playing program (Epstein et al. 1996). The module supports moves that result in states that are members of the mill formation concepts described above. We tested this augmented version of Hoyle against an expert program in the game of 5 men's morris. Hoyle played 200 training contests against the expert, followed by 10 testing contests, in each of 5 runs. The new module was found to vote in a manner that was consistent with expert play.

Acknowledgments

This work is partially supported under an NSF Graduate Fellowship, NSF Grant #9423085 and the New Jersey Center for Multimedia Research. We acknowledge helpful discussions with Ron Kinchla and Jim Bergen.

References

Epstein, S. L., Gelfand, J. and Lesniak, J. (1996) Pattern-based learning and spatially-oriented concept formation with a multi-agent, decision-making expert. *Computational Intelligence*, 12, 199-221.

Flann, N. S. and Dietterich, T. G. (1986). Selecting appropriate representations for learning from examples. *Proceedings of the Fifth National Conference on Artificial Intelligence* (pp. 460-466). Menlo Park, CA: The AAAI Press.

Olson, D. R. and Bialystok, E. (1983). *Spatial cognition: the structure and development of mental representations of spatial relations*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Rogers, E. (1995). A cognitive theory of visual interaction. In J. Glasgow, N. H. Narayanan & B. Chandrasekaran (Eds.), *Diagrammatic Reasoning*. Menlo Park, CA: The AAAI Press.

Wisniewski, E. J. (1995). Prior knowledge and functionally relevant features in concept learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 21, 449-468.