Commentary on Hommel, Musseler, Aschersleben, and Prinz

Perception, Action Planning, and Cognitive Maps

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Abstract
Perceptual learning mechanisms derived from Hebb's theory of cell assemblies can generate prototypic representations capable of extending the representational power of TEC event codes. The extended capability includes categorization that accommodates "family resemblances" and problem solving that uses cognitive maps.

It was almost 60 years ago that the brilliant Cambridge psychologist K. J. W. Craik (1943, p. 61) observed:

> If the organism carries a "small-scale model" of external reality and of its own possible actions within its head, it is able to try out various alternatives, conclude which is the best of them, react to future situations before they arise, utilize the knowledge of past events in dealing with the present and future, and in every way to reach in a much fuller, safer, and more competent manner to the emergencies which face it.

Craik's description is clearly based on the assumption that actions and objects share space in the internal model. Comparably, Tolman's (1948) cognitive map concept implicitly incorporated both action and objects. In fact, MacCorquodale and Meehl (1954) provided a translation of Tolman's concept in their S_1-R_1-S_2 framework. Their formulation of the cognitive map codes the following information: if the organism were to take some action, R_1, in the context of a given situation S_1, a new situation S_2 would result.

This suggests that there is a close kinship between the theory of event coding and the world of cognitive maps and internal models. A cognitive map is an internal representation of an environment that is used in much the same way that Craik proposes. Cognitive maps are representations of navigable environments. These representations must also be navigable if they are to be useful as tools for planning or reacting to events. It is difficult to imagine, for example, how one would model a world for navigation if one did not explicitly include a model of movement. Fortunately, one of the simplest, most efficient ways to model experience also naturally encodes actions. The PLAN cognitive mapping model (Chown, et al., 1995), for example, stores schematic visual scenes capturing information in analogous fashion to how it was originally processed. Representations of this type have been called ‘semantically transparent’ by Smolensky (1988) who argues that such representations are efficient because they do not require extra processing to convert them from one form to another. Cognitive mapping models such as PLAN are based on the notion that experience is sequential, with each transition in the sequence arising as the result of an action (locomoting in the case of a cognitive map for navigation). With subsequent experience, such sequences are overlayed forming a kind of network. Planning with such structures, therefore, is a matter of finding an appropriate sequence from start to goal in the network structure. Since the actions are implicitly a part of the representation, they will be naturally extracted as part of the plan. Such structures take the TEC construct a step further by explicitly proposing the form of the internal representation at the cognitive map level.

This kind of network structure derived from experienced sequences of actions is also the basis for the internal representation of the constituent elements of a cognitive map: the representations of percepts, actions, and their relationships. A key issue at this level of representation is perceptual generalization, the process that allows diverse stimulus patterns to be placed in the same category. The event codes proposed in TEC rely on common features and hierarchical abstractions to achieve this important capability. While this approach is a useful beginning, it does not provide all of the necessary functionality. Humans are capable of learning prototypes or “natural categories” in which no fixed subset of features is necessary and sufficient for category membership. In fact, some members in a category may share no common features at all, having only a “family resemblance” as the basis for category membership (Rosch, 1978). These observations apply to perceptual categories, action categories, and event categories integrating perceptions and actions. The key to handling the challenges posed by natural categories and family resemblance is to look carefully at the process of perceptual learning. The authors make a key observation along these lines by noting that “perceiving the world is a process of actively acquiring information about the perceiver-environment relationship, including all sorts of movements of eye, hands, feet, and body…”(p. 34). Perceptual learning mechanisms derived from Hebb's (1949) theory of cell assemblies can generate prototypic representations capable of handling family resemblances (Posner, 1973, 1986). Moreover, related control mechanisms ensure that the activation of overlapping or alternative representations will result in a single, definite perceptual outcome (Kinsbourne, 1982; Kaplan et al., 1990). For these reasons, the cell assembly framework appears to provide a natural way to extend the representational power of TEC event codes, both intrinsically and as elements of a cognitive map.

Note that cognitive maps are not limited to navigation in the traditional sense of the word, merely to navigable environments, and it is of course an action space that makes an environment navigable. Any semantically transparent structure with an implicit model of actions will naturally provide a basis for problem solving using the same idea of extracting a sequence from a starting location to a goal location inherent in navigation domains. Models of this type, notably using reinforcement learning (Kaelbling, et al., 1996), have begun to supplant more traditional planners in AI systems because generic structures and uniform methodology can be applied and easily learned in virtually any problem solving environment. These observations also apply to cognitive maps and environments that require explicit models of actions. The same mechanisms that generate explicit prototypes for perceptual categories will also produce explicit prototypes for action categories. The same mechanisms that provide for flexible navigation and way-finding can also be used for opportunistic problem solving using explicit action models. In this sense, cognitive maps and the mechanisms that generate and use them are truly generic. The ability to create such generic structures and methods will necessarily be an important step in the development of the TEC model.

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