Modeling Interaction and Integration of Perception and Action

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Introduction

To account for perceptual and action-related stages of information processing, most prominent cognitive architectures have extended their coverage from primarily cognitive processes to perceptual processing and response execution (e.g. EPIC (Kieras & Meyer, 1997); ACT-R/PM (Byrne & Anderson, 1998)). However, despite these extensions they are typically still too limited to explain some well-known phenomena from the perception-action domain in cognitive psychology such as stimulus-response compatibility effects (e.g., Simon Effect (Simon & Rudell, 1967), and action preparation influences on perception (e.g., Müsseler & Hommel, 1997). These phenomena suggest that perception and action are more intimately related than these architectures allow for. We are currently developing HiTEC (Haazebroek, Raffone & Hommel, submitted), a novel cognitive architecture that stresses both the interaction and integration between perception and action.

Here we describe the overall structure and general principles of HiTEC and we demonstrate how a variety of psychological phenomena in the perception-action domain can be replicated using computer simulations of the model.

HiTEC

As shown in Figure 1, HiTEC consists of three levels: the sensorimotor level, the common coding level and the task level. At the sensorimotor level, stimuli are encoded by activating sensory codes. Motor actions are executed by activating motor codes. Sensory codes and motor codes are both connected to feature codes at the common coding level. These feature codes represent a-modal perceptual features (e.g., location, intensity et cetera). Crucially, both stimulus features (e.g., location of a tone) and response features (e.g., location of a key press) are encoded using these common codes, thereby allowing for two-way interaction between stimuli and responses (Hommel et al., 2001).

Feature codes are connected to task codes at the task level. These connections reflect the task instruction allowing the model to respond according to specified stimulus-response (S-R) mappings. By dynamically setting up these connections, different S-R mappings can be implemented, allowing the model to simulate a variety of tasks, while keeping all other codes and connections unchanged.

Within the levels, codes are arranged in maps. Sensory codes are contained in sensory maps, corresponding to sensory dimensions (e.g., color), feature codes are contained in feature maps reflecting more cognitive feature dimensions (e.g., global location). At the task level there is one map containing task codes representing the different response alternatives within the current task. There is also one motor map containing motor codes representing a limited number of specific movements.

In the HiTEC architecture, stimulus processing and response selection are one and the same process: stimuli activate certain sensory codes, activation flows through the model and at all levels interaction takes place, letting the model converge to a condition with only one motor code having an activation value above a set threshold. This results in the selection of that motor action and execution of the corresponding response.

In addition to this propagation of activation there are integration processes at work that temporarily bind feature codes into event files (Hommel, 2004). These event files - illustrated by the gray feature codes in Figure 1 - modulate the overall dynamics of the model, by selectively enhancing feature codes belonging to one event file and at the same time making them less available to other processes.

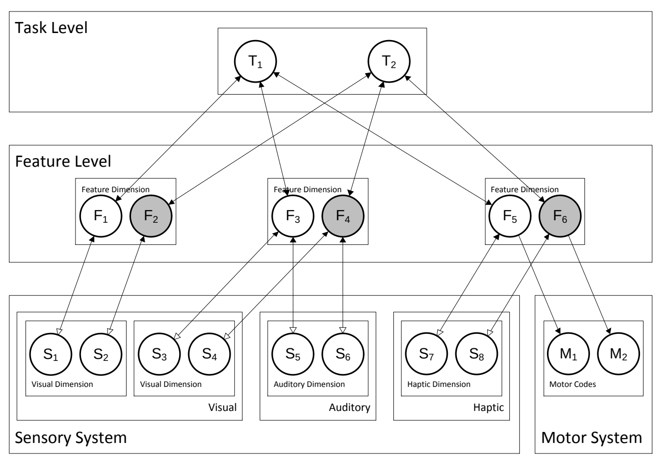

Figure 1: General structure of HiTEC architecture. Circles denote codes, lines denote connections, rectangles are maps, and gray feature codes belong to the same event file.

The above mentioned principles that govern the dynamics in HiTEC are strongly based on both theoretical and empirical work in cognitive psychology. By integrating them into a cognitive architecture that can be used to simulate a variety of well-known phenomena we aim at obtaining a richer understanding of the intricate interplay between perception and action than theory alone can provide.

Other cognitive architectures such as EPIC and ACT-R/PM do address perceptual and motor related aspects of human performance. However, these architectures differ on several crucial aspects. Where HiTEC treats perceptual processing as part of the overall 'translation process' and therefor allows perception to be modulated by task preparation and even action planning, EPIC and ACT-R/PM treat this perceptual stage as 'additional waiting time' before the cognitive core system (using production rules) can start to work. In similar vein HiTEC treats action planning as part of the overall 'translation process', susceptible to influences from perception and task set.

Thus, where other architectures focus on the cognitive middle 'stage' between perception and action, HiTEC puts perception and action – and their interplay – at the center treating cognition mainly as a modulatory influence. By assuming common codes for both perception and action interactions can occur that are impossible when segregating perceptual, cognitive and motor stages as is common in other architectures. These interactions allow the replication of empirical phenomena related to stimulus-response crosstalk (both enhancement and impairment).

HiTEC is not yet as mature as other cognitive architectures and cannot be readily used to model the diversity of tasks that other architectures have been shown to successfully replicate. Yet, by taking perception-action as primary perspective we provide a line of research that complements existing approaches in cognitive architectures.

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