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Biologically Inspired Architectures for Anticipation Based Sensorimotor Perception

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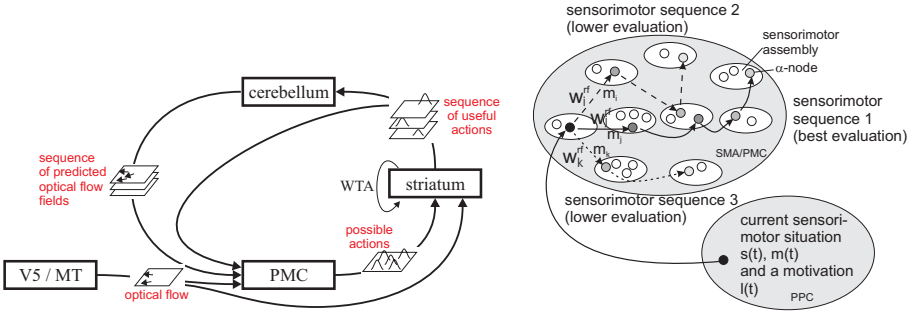
Central Idea: Based on novel sensorimotor theories of perception, we developed a new approach that avoids the common separation of perception and generation of behavior and fuses both aspects into a consistent neural process. Perception is regarded to be an active process which anticipates the sensory consequences of alternative hypothetical interactions with the environment. This view emphasizes the generative character of perception considering both sensory and motor aspects of the action-perception-cycle.

Biological evidence: A variety of cortical and subcortical subsystems are involved in the sensorimotor anticipation process: (1) Relevant information from the current situation is extracted by the posterior parietal cortex by integration of different sensory inputs. (2) Planning of motor actions as taking place in the secondary motor areas or internal simulation as supposed in the lateral cerebellum are enrolled to anticipate sensorimotor alternatives as a kind of low-level mental 'rehearsal'. (3) Basal ganglia (BG) integrate information from many cortical areas in order to evaluate and select an appropriate sensorimotor sequence utilizing associations learned by conditioning or reinforcement learning.

Architectures: Two architectures are presented. The first is the Model for Anticipation based on Sensory IMagination (MASIM, left figure). It realizes a sequential search in sensorimotor space using a simple model of lateral cerebellum (LC) as sensory predictor. The central idea are two reentrant cortico-cortical loops via BG or LC respectively, which are passed through repeatedly in order to simulate internally alternative sensorimotor sequences. The second approach, our Model for Anticipation based on Cortical Representations (MACOR, right figure) allows a completely parallel search at the neocortical level using assemblies of neurons for generation, grouping, separation, and selection of sensorimotor sequences. Sensory situations are encoded by assemblies, which contain α-nodes that represent the motor context resulting in the respective situation. The connection between the α-nodes encode the motor commands (m) along with their evaluations (w^{r}) and competence (w^{c}) for the corresponding sensorimotor transition.



Both models are intended as general schemes for sensorimotor anticipation in neural architecture. We try to capture some general properties relevant to our "perception as anticipation"-approach in brain-like systems.

Experimental framework: To evaluate the perceptual performance of the systems, observable behaviors are the only indicators. Therefore, we investigate our anticipatory concept within a simple local navigation behavior of a mobil system. Of great importance for a successful navigation behavior is the evolution of a general understanding of space and shape, independent of specific visual details of the objects in the scene. In our view, the evolution of such a general understanding must be based on the capability to continuously simulate, evaluate, and select sensorimotor alternatives. This requires a generative process of anticipating the course of events resulting from different sequences of actions. We demonstrate the efficiency of our model approaches with first encouraging results demonstrating that an anticipative system leads to a better local navigation than a reactive one.