Part I
Computational Neuroscience Models

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In this part, leading computational neuroscientists present neural network models of the various components of the perception–action cycle, namely perception, attention, cognitive control, decision making, conflict resolution and monitoring, knowledge representation and reasoning, learning and memory, planning and action, and consciousness at various levels of detail. The architectures of these models are *heavily* guided by knowledge of the human and animal brain. The models then allow the synthesis of experimental data from different levels of complexity into a coherent picture of the system under study.

In the chapter entitled "The role of attention in shaping visual perceptual processes", Tsotsos and Rothenstein argue that an optimal solution to the generic problem of visual search, which is robust enough to apply to *any* possible image or target, is unattainable because the problem of visual search has been proven intractable. The brain, however, is able to solve this problem effortlessly and hence that poses a mystery. To solve this mystery, Tsotsos and Rothenstein argue that the brain is not solving that same generic visual search problem *every time*. Instead, the nature of the problem solved by the brain is fundamentally different from the generic one. They describe a biologically plausible and computationally well-founded account of how the brain might deal with these differences and how the attentional brain mechanisms dynamically shape the visual perceptual processes of humans and animals.

In the next chapter entitled "Sensory fusion", Ursino, Magosso and Cuppini present two computational models of multisensory integration, inspired by real neurophysiological systems. The first model considers the integration of visual and auditory stimuli in the superior colliculus, whereas the second one considers the integration of tactile stimuli and visual stimuli close to the body to form the perception of the peripersonal space. Although both models attack different problems, the mechanisms delineated in the models (lateral inhibition and excitation, nonlinear neuron characteristics, recurrent connections, competition) may govern more generally the fusion of senses in the brain. The models, besides improving our comprehension of brain function, drive future neurophysiological experiments and provide valuable ideas to build artificial systems devoted to sensory fusion.

In the chapter entitled “Modeling memory and learning consistently from psychology to physiology”, Coward describe the Recommendation Cognitive Architecture that maps the information model for each major anatomical brain structure into more detailed models for its substructures, and so on all the way down to neuron physiology. The architecture explains how the more detailed models are implemented physiologically, and how the detailed models interact to support higher level models, up to descriptions of memory and learning on a psychological level.

In the chapter entitled “Value maps, drives and emotions”, Levine discusses value maps, drives and emotions through the modelling of decision making, judgment and choice. He presents the Distributed Emotional Connections Influencing Decisions and Engaging Rules (DECIDER) model, which is based on interactions among a large number of brain regions such as loci for emotions (amygdala and orbital prefrontal cortex), rule encoding and executive function (orbital and dorsolateral prefrontal and anterior cingulate), and behavioural control (striatum, thalamus and premotor cortex). In order to incorporate the capacities for using either heuristic or deliberative decision rules in real time in a changing and uncertain environment, the model addresses a variety of questions concerning the interface between emotional valuation and numerical calculation.

In the chapter entitled “Computational neuroscience models: Error monitoring, conflict resolution and decision making”, Brown and Alexander discuss computational neuroscience models of how performance monitoring and cognitive control can monitor the outcomes of decisions and actions and depending on the success of these actions in achieving the desired goals can implement corrective actions as quickly as possible.

In the chapter entitled “Neural network models for reaching and dexterous manipulation in humans and anthropomorphic robotic systems”, Gentili, Oh, Molina and Contreras-Vidal present a modular neural network model able to learn the inverse kinematics of an anthropomorphic arm [7 degrees of freedom (DOF)] and three fingers (4 DOFs) and perform accurate and realistic arm reaching and finger grasping movements. They present the model’s architecture in detail including both the model’s components and parameters. They show simulation results of the proposed model and discuss them in terms of their biological plausibility and model assumptions. Finally, they conclude with their model’s limitations along with future solutions that could challenge it.

In the chapter entitled “Schemata learning”, Nishimoto and Tani describe a dynamic neural network model that accounts for the neuronal mechanism of schemata learning. Schemata learning refers to sequences of actions on objects learnt as “schemata” by humans, so as to be able to function in fast, even an automatic, manner in many well-known situations (e.g. going to a restaurant, going to bed, etc). Their model shows that the functional hierarchical structures that emerge through the stages of development assist through their fast and slow dynamics behaviour primitives and motor imagery to be generated in earlier stages and compositional sequences of achieving goals to appear in later stages. They conclude with a discussion on how schemata of goal-directed actions could be acquired with gradual development of the internal image and compositionality for the actions.

In the chapter entitled "The perception-conceptualisation-knowledge representation-reasoning representation-action cycle: The view from the brain", Taylor considers new and important aspects of brain processing related to perception, attention, reward, working memory, long-term memory, spatial and object recognition, conceptualization and action, and how they can be melded together in a coherent manner. His approach is based mainly on work done in the EU GNOSYS project to create a reasoning robot using brain guidance, starting with the learning of object representations and associated concepts (as long-term memory), with the inclusion of attention, action, internal simulation and creativity.

In the chapter entitled "Consciousness, decision making and neural computation", Rolls describes a computational theory of consciousness named higher order syntactic thought (HOST). He argues that the adaptive value of higher order thoughts is to solve the credit assignment problem that arises if a multi-step syntactic plan needs to be corrected. He suggests qualia arise secondarily to higher order thoughts and sensations and emotions are there because it is unparsimonious for the organism *not* to be able to feel something. Brain-inspired models of decision making are described based on noise-driven and probabilistic integrate-and-fire attractor neural networks, and it is proposed that networks of this type are involved when decisions are made between the explicit and implicit routes to action. Rolls argues that the confidence one has in one's decisions provides an objective measure of awareness, but it is shown that two coupled attractor networks can account for decisions based on confidence estimates from previous decisions. On the implementation of consciousness, Rolls shows that the threshold for access to the consciousness system is higher than that for producing behavioural responses. He argues that the adaptive value of this may be that the systems in the brain that implement the type of information processing involved in conscious thoughts are not interrupted by small signals that could be noise in sensory pathways. He concludes that oscillations are not a necessary part of the implementation of consciousness in the brain.

In the final chapter entitled "Review of models of consciousness", Taylor reviews the main computational models of consciousness and develops various tests to assess them. Although many models are successful in passing some of these tests under certain conditions, only one model (the CODAM model) is able to pass all of them.