Part II
Cognitive Architectures

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In this part, leading computational scientists present architectures, algorithms and systems empowered with cognitive capabilities 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 machine consciousness. These systems are *minimally* guided by knowledge of the human and animal brain. Instead, they make use of knowledge from the areas of cognitive science, computer vision, cognitive robotics, information theory, machine learning, computer agents and artificial intelligence.

In the chapter entitled "Vision, attention control and goals creation system", Rapantzikos, Avrithis and Kollias present computation solutions to the four functions of the attentional process: (1) the *bottom-up* process, which is responsible for the *saliency* of the input stimuli, (2) the *top-down* process that bias attention towards known areas or regions of pre-defined characteristics, (3) the *attentional selection* that fuses information derived from the two previous processes and enables focus and (4) the *dynamic evolution* of the attentional selection process.

In the chapter entitled "Semantics extraction from multimedia data: an ontology-based machine learning approach", Petridis and Perantonis present a machine learning method for extracting complex semantics stemming from multimedia sources. The method is based on transforming the inference problem into a graph expansion problem, expressing graph expansion operators as a combination of elementary ones and optimally seeking elementary graph operators. The latter issue is then reduced to learn a set of soft classifiers, based on features each one corresponding to a unique graph path. The advantages of the method are demonstrated on an athletics web-pages corpus, comprising images and text.

In the chapter entitled "Cognitive algorithms and systems of episodic memory, semantic memory and their learnings", Zhang reviews cognitive systems that mimic human explicit memory and its impairments in anterograde, retrograde and developmental amnesias, and semantic learning deficit.

In the chapter entitled "Motivational processes within the perception-action cycle", Sun and Wilson present the CLARION cognitive architecture. The CLARION

is an integrative cognitive architecture, consisting of a number of distinct subsystems with specific functionalities: action control, general knowledge maintenance, motivation and drives, and action control and modification based on the action's success or failure.

In the chapter entitled "Error monitoring, conflict resolution and decision making", Lima addresses the problem of plan representation, analysis and execution in multi-robot systems using a well-known formal model of computation: Petri nets. He reviews some of the Petri net-based approaches to robot task modelling described in the literature, the formal models they introduced and some of the results obtained. He then introduces his proposed multi-robot task model, the corresponding plan representation by Petri nets, how to analyse plan performance in the presence of uncertainties and some examples of application to robot soccer. He concludes with a summary on what has been accomplished so far under this line of research, the success stories, limitations found, future challenges and some suggestions on how to address their solution.

In the chapter entitled "Developmental learning of cooperative robot skills: a hierarchical multi-agent architecture", Karigiannis, Rekatsinas and Tzafestas present a new framework of developmental skill learning process by introducing a hierarchical multi-agent architecture. The model is then tested and evaluated in two numerical experiments, one related to dexterous manipulation, and the other to cooperative mobile robots.

In the chapter entitled "Actions and imagined actions in cognitive robotics", Mohan, Morasso, Metta and Kasderidis describe the various internal models for real and mental action generation developed in the GNOSYS Cognitive architecture and demonstrate how their coupled interactions can endow the GNOSYS robot with a preliminary ability to virtually manipulate neural activity in its mental space to initiate flexible goal-directed behaviour in its physical space. The performance of these models is then tested against various experimental conditions and environments.

In the chapter entitled "Cognitive algorithms and systems: reasoning and knowledge representation", Garcez and Lamb describe computational models with integrated reasoning capabilities, where the neural networks offer the machinery for cognitive reasoning and learning, while symbolic logic offers explanations to the neural models facilitating the necessary interaction with the world and other systems.

In the chapter entitled "Information theory of decisions and actions", Tishby and Polani address the question of in what sense the "flow of information" in the perception–action cycle can be described by Shannon's measures of information introduced in his mathematical theory of communication. They describe that decision and action sequences turn out to be directly analogous to codes in communication, and their complexity – the minimal number of (binary) decisions required for reaching a goal – directly bounded by information measures, as in communication. They consider the future expected reward in the course of a behaviour sequence towards a goal (value-to-go) by estimating the cumulated information processing cost or bandwidth required to specify the future decision and action sequence (information-to-go). They conclude by obtaining new algorithms for calculating the optimal

trade-off between the value-to-go and the required information-to-go, unifying the ideas behind the Bellman and the Blahut-Arimoto iterations.

In the final chapter entitled “Artificial consciousness”, Chella and Manzotti provide answers to what is consciousness, whether it is a physical phenomenon and how can it be replicated by an artificial system designed and implemented by humans.