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The Distributed Adaptive Control Architecture of the Embodied Situated Mind

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Introduction

This tutorial introduces the Distributed Adaptive Control (DAC) theory of the principles underlying the Mind, Brain, Body Nexus (MBBN) that has been developed over the last 20 years (Verschure, 2003; Verschure, 2016). DAC assumes that the brain maintains stability between an embodied agent, its internal state and its environment through action. It postulates that in order to act, or know how, the brain has to optimize 5 fundamental objectives which can be labeled as: why, what, where, when and who. Thus the function of the brain is to continuously solve the so-called H5W problem with 'H' standing for the 'How' an agent acts in the world. The DAC theory is expressed as a neural-based architecture implemented in robots and organized in two complementary structures: layers and columns. The organizational layers are called: reactive, adaptive and contextual, and its columnar organization defines the processing of states of the world, the self and action or the interaction between the first two.

After an overview of the key elements of DAC, the mapping of its key assumptions towards the invertebrate and mammalian brain is described. The general overview of DAC's explanation of MBBN is combined with examples of application scenarios in which DAC has been validated, including mobile and humanoid robots, neuro-rehabilitation and the large-scale interactive space Ada. In this tutorial we will provide the elements necessary to implement an autonomous control system based on the DAC architecture and we will explore how the different layers of DAC contribute to solving a foraging task

Foraging is an advanced, goal-oriented behavior where prior knowledge of an environment and acquired behavioral strategies must be matched to the novelty and the hazards presented by an unpredictable world. DAC is based on the fundamental assumption that foraging can be explained on the basis of the interaction of three layers of control: reactive, adaptive and contextual. DAC was originally proposed as model for classical and operant conditioning. The reactive layer provides a set of reflexes allowing the system to interact with the environment – unconditioned stimuli to unconditioned responses. The adaptive layer is a model of classical conditioning and fulfills a twofold task. On the one hand it learns to associate the conditioned stimuli to the unconditioned responses, forming the conditioned responses. On the other hand, it forms internal representations of the conditioned stimuli, which are used by the contextual layer. We can define it as acquiring and shaping the agent-environment specific state space. The contextual layer is a model of operant conditioning providing the system with short and long term memory structures. The sensorimotor contingencies formed at the level of the adaptive layer are acquired and retained in these memory structures, forming behavioral sequences or policies. The representations stored in the contextual layer are constantly matched against the ongoing perceptions allowing for the retrieval of successful behavioral sequences in similar contexts.

The prototypical robot test case for DAC is a foraging task in an open arena. In this task, the robot, equipped with proximal and distal sensors, explores the arena in search of light sources while avoiding collisions with the surrounding wall. Colored patches on the floor serve as landmarks for navigation. In the framework of classical conditioning, the proximal sensors (e.g., distance and light) serve as aversive and appetitive unconditioned stimuli. Close to the light or when colliding with the wall an unconditioned response is triggered such that the robot approaches the light or turns away from the wall. The colored patches serve as conditioned stimuli. A visualization of such a task can be seen in Figure 1.

In this tutorial students will learn how to control the robot through the DAC architecture implemented using the IQR neuronal networks simulator (Bernardet et al., 2010) interfaced with the Gazebo robot simulator (Koenig et al., 2004) as seen in Figure 2. IQR implements the neuronal modules of the brain of the agent and Gazebo acts as the server of the simulated 3D environment. A VirtualBox Ubuntu virtual machine with a fully configured simulation setup and the DAC book (available at http://csnetwork.eu/CSN%20Book%20Series) accompany this tutorial.

Presenter

Paul Verschure is a professor at Universitat Pompeu Fabra, research professor at the Catalan Institute of Advanced Research and director of the Center of Autonomous Systems and Neurorobotics in Barcelona (Spain). His scientific aim is to find a unified theory of mind, brain and body through the use of synthetic methods and to apply such a theory to the development of novel cognitive technologies. Paul Verschure has pursued his research at different institutes in the US (Neurosciences Institute and The Salk Institute, both in San Diego) and Europe (University of Amsterdam, University of Zurich and the Swiss Federal Institute of Technology-ETH and Universitat Pompeu Fabra in Barcelona). Prof. Verschure works on biologically constrained models of perception, learning, behavior and problem solving that are applied to wheeled and flying robots, interactive spaces and avatars. He maps these models to societal impact in the domains of health, cultural heritage and education. The results of these projects have been published in leading scientific journals including Nature, Science, PLoS, Neuron, Proceedings of the Royal Society and PNAS.

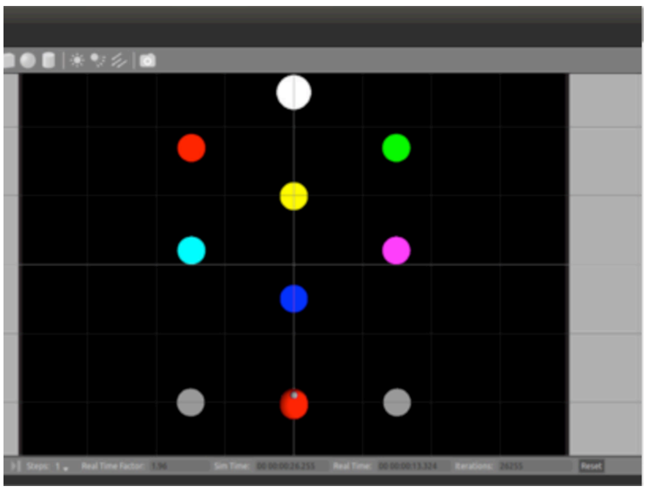

Figure 1: Gazebo robot simulator. Screenshot of Gazebo simulator showing the prototypical top view of a foraging task used to benchmark DAC with colored patches on the floor and a source of light represented by a bigger white patch on top of the screen.

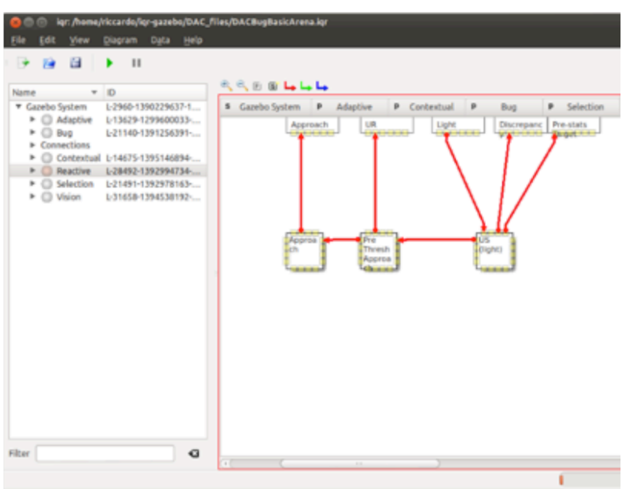

Figure 2: The IQR Neural Simulator. Screenshot of IQR showing a neural based implementation of the reactive layer.

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