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Simulation of serotonin mechanisms in NEUCOGAR cognitive architecture

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Abstract

This work aims at demonstrating that the neuromodulatory mechanisms that control the emotional states of mammals (specifically rat's brains) can be represented and re-implemented in a computational model processed by a machine. In particular we specifically focus on two neurotransmitters, serotonin and dopamine, starting from their fundamental role in basic cognitive processes. In our specific implementation, we represent the simulation of the 'disgust-like' state based on the three dimensional neuromodulatory model of affects or emotions, according to the 'cube of emotions'. These functional mechanisms can be transferred into an artificial cognitive system: inhibition, for example, can elicit a blocking behaviour that, depending on its intensity and duration, can push the system to a general emotional state. We have simulated 1000 milliseconds of the serotonin and dopamine systems using NEST Neural Simulation Tool with the rat brain as the model to artificially reproduce this mechanism on a computational system.

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Keywords: Serotonin, dopamine, disgust, artificial intelligence, simulation, affective computing, emotion modelling, neuromodulation

1 Introduction

The current rapid developments in neurocognitive sciences and new discoveries related to the core mechanisms of natural intelligence have triggered new insights and opportunities in the field of biologically inspired cognitive systems [20].

On the other hand, this epistemological revolution has also changed classic ideas about cognition, especially those related to the connection between emotions and cognitive processes [3, 12]. This key factor of cognitive processing has therefore been implemented into artificial cognitive systems, considering new and reliable data related to a key aspect which builds the entire cognitive processes architecture: emotions [15].

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As a starting point of our model, we consider a simple "fear", which is necessary to evaluate "fly-or-fight" actions [21]. Our study focuses on two opposing and complimentary neuromodulators: dopamine and serotonin [5]. Dopamine is related to brain reward processes, while serotonin is implied into aversive or inhibitory processes; used in combination we may design a system that manages 'fly-or-fight' actions in which several learning procedures could be easily implemented. Can be easily understood the fundamental role of both neurotransmitters into the learning processes [25, 14, 8].

We argue that our proposal represents a milestone in the creation of a new generation AI incorporating the option to create neuromodulatory architectures which can run over several conceptual models, languages and systems. The proposed approach is designed to model human cognitive processes such as: creating unique and plastic cognitive identities. This is a basic, but solid, first step towards grounded cognitive systems that share across the whole cognitive multi-heuristic architecture the same controlling mechanisms: synthetic neuromodulators.

2 The problem

The complete set of emotions related mechanisms currently is under the heavy interest [1, 19, 10, 7, 2, 4]. Researchers in the domain already indicated that emotions are fundamental part of human cognition including following functions: **attention**, **motivation**, **strategy selection**, **mood disposal**, **learning**, **reaction**, and **invention**, among a long list. Following [18], we need to consider that recent behavioral, neuropsychological, neuroanatomy, and neuroimaging research, suggests that emotion interacts heavily with cognition in the brain. In fact, emotional circuitry is not different and accessory to main brain architecture, but it is mixed and integrated into main cerebral processes: "emotion" and "cognition" may be used as labels in the context of certain behaviours, but do not map clearly into compartmentalized pieces of the brain. This evidence pushed us to consider the necessity of creating computational architectures with a bioinspired emotional design from scratch, instead of adding some kind of complementary emotional module to be attached to pre-existing architectures, as a superficial "emotional flavour" system.

Following bioinspired methodology, we identify emotional brain mechanisms based mammals, specifically rat's model of a brain. The question of bio-realism seems to be quite important from the emotions definition perspective.

3 Our idea

For the re-implementation of bio-realistic computing model of emotions we have used work of Hugo Lovheim[13] the "cube of emotions". His ideas are based on the role of three monoamine neuromodulators: serotonin, dopamine, noradrenaline. Based on roles of the neuromodulators we have created a mapping from one neuropsychological model of affects in order to implement it into computing system parameters. These neuromodulators creates axis of the 3D model of 8 affects (inborn emotional reactions) inherited from works of Silvan Tomkins [9]. The figure 1 indicates the two dimensional model of mapping in which levels of neuromodulators are mapped to simulate affects. For a detailed exposition see our previous articles: [23, 11, 22, 24], where we have demonstrated successful re-implementation of the dopamine system of a rat brain in a computational system.