Architecture of Mind Considering Integration of Genetic, Neural, and Hormonal System

Stevo Bozinovski[1], Liljana Bozinovska[2]

[1]Electrical Engineering Department, University of Skopje, Skopje, Macedonia

[2]Physiology Institute, Medical Department, University of Skopje, Skopje, Macedonia

bozinovs@rea.etf.ukim.edu.mk

Abstract

The problem of building an architecture of a mind which appreciates three crucial systems from biology: genetical, neural, and hormonal systems, is considered. It is presented a generic architecture and a derivate, an emotion learning architecture. A learning rule which explicitly implements the influence of the mentioned three systems is proposed.

1. Introduction: Problem Statement

Although in earlier stage most AI approaches insisted on symbolic reasoning with no particular reference to biology, most contemporary AI approaches show interest to concepts as artificial neural networks and genetic algorithms, evidently motivated by biology. However, biological agents exhibit behavior that is also influenced by the hormonal system. That motivates statement of the following problem:

Find architecture of mind that will implement neural, genetic, and hormonal control.

Symbolically, we need agent architecture with the following control function:

Behavior = Control(Neural, Genetic, Hormonal)

That problem we call the problem of integrated biology-inspired (IBI) control. In particular we are interested in *learning architectures* with a property of IBI control.

2. A Conceptual Architecture

Our approach toward IBI architecture for an agent is shown in Figure 1. As Figure 1 shows, the agent, from the *genetic environment,* inherits initial states of its memory and also other initial parameters for behaving in the *behavioral environment*. The main control system, the neural system, controls the motor response of the agent, including the secretory response of the glands. It controls the hormonal system, which in turn can produce emotions, moods, and other states of the consciousness that affect the nervous system. Through the behavioral environment interface the agent interacts with the behavioral environment. The operating system supplies features such as priorities, preferences, goals, needs, queues, activation strategies, thresholds, among other parameters and functions required for cooperation between the mentioned systems within an agent.

The agent can learn and adapt to a changing environment. The agent is able to import and export genomes, data structures reflecting the adaptation of the agent in the considered environment.

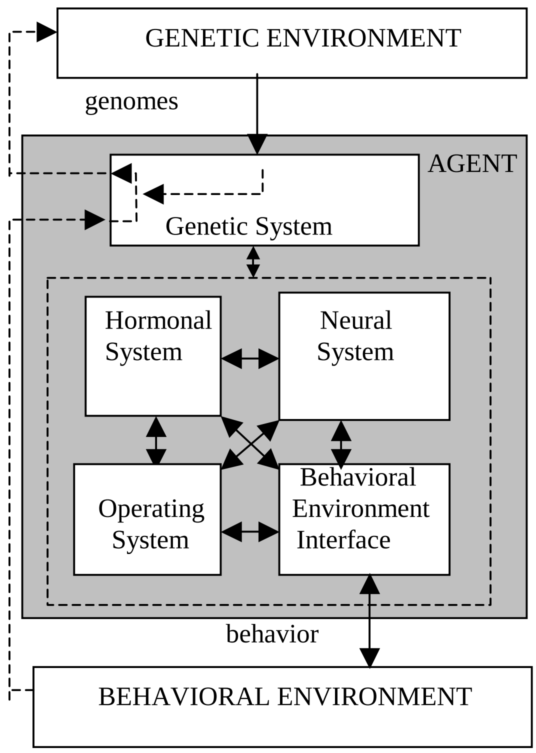

Figure 1. A generic IBI control architecture

In the genetic environment, genomes are transferred to other agents, to speed up the adaptation of the new generation of agents in the behavioral environment.

3. A Working Architecture

Figure 2 shows an architecture, which can be viewed as derived from the architecture shown in Figure 1. In this IBI architecture instance, the neural system is represented by a crossbar connected neural weights matrix, the hormonal system influences emotions, the behavior environment interface receives situations and computes actions, while the operating system supplies only some personality parameters, such as curiosity to action selection and sensitivity threshold to emotion computation.

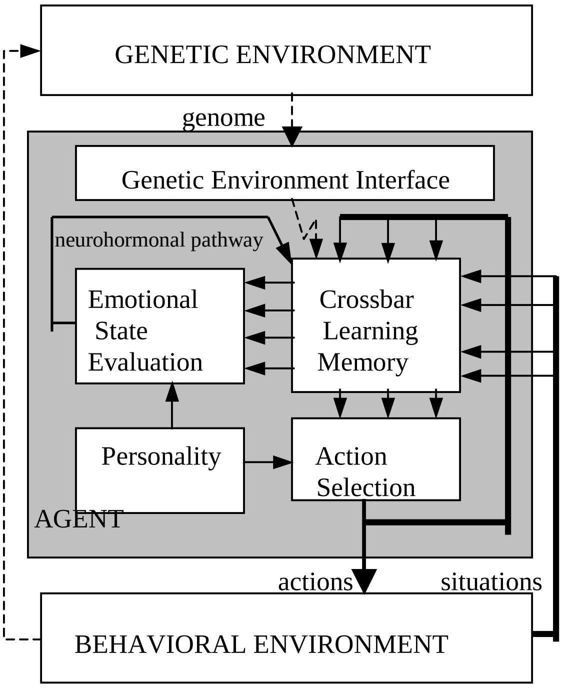

Figure 2. The CAA agent architecture

A crossbar computing procedure over the weights matrix is used for computing emotions (column-wise) and actions (row-wise). This architecture we call Crossbar Adaptive Array (CAA) architecture.

4. Emotion Learning

It is assumed that each crossbar element, w_{aj}, represents an emotion, *Emotion(a,j)*, of performing action *a* in situation *j*. Having that, CAA performs its *crossbar emotion learning procedure*, which has four steps:

1) state *j*: choose an action in situation: (let it be action *a*; let the environment returns situation *k*)
2) state *k*: *feel the emotion* for state *k*: *emotion(k)*
3) state *j*: *learn the emotion* for *a* in *j*: *Emotion(a,j)*
4) change state: *j=k*; goto 1

This learning procedure is an emotion backpropagation procedure (secondary reinforcement learning procedure). The learning rule used in CAA in step 3), is

$$Emotion^{o}(a,j) = genome^{o}(envir) \qquad (1a)$$
$$Emotion'(a,j) = Emotion(a,j) + emotion(k) \qquad (1b)$$

It is a simple learning rule, which just adds the *emotion of being* in the consequence situation, *k*, to the *emotion toward* performing action *a* in situation *j* on which *k* is the consequence.

5. Related work

In this short paper we presented some conceptual issues related to the CAA architecture. Implementations are described in Bozinovski (1999), and Bozinovski et. al. (1999). The work presented here is related to contemporary reinforcement learning research (see Barto, 1997) and contemporary emotion research (see Castelfranchi, 2000).

6. Conclusion

The learning rule (1) includes influence from the genetic environment, which is assumed to reflect the behavioral environment, and performs emotion learning, where *emotions are signaled by the hormonal system and are stored in the neural system*.
Symbolically, we can rewrite (1) as

$$neural^{o}(a,j) = genetic^{o}(envir) \qquad (2a)$$
$$neural'(a,j) = neural(a,j) + neurohormonal(k) \qquad (2b)$$

It is a learning rule of an IBI architecture we were searched for.

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