Towards a physiological model of emotions: first steps

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Abstract

This paper presents the Physiological Model of Emotions. This model is our first step towards dealing with intelligence from a biological point of view. The behavior of each component is evaluated in an independent form thus avoiding abstractions that do not resemble the body's functioning. Therefore, the Physiological Model of Emotions contains a simplified organism including only a restrict group of organs and tissues constantly generating different stimuli and acting as generator of intentions. The model also differs from cognitive approaches and considers a restricted set of emotional states with significantly different physiologic manifestations in the body influencing the decision-making. The small set of organs can produce different physiological states when the organism is eating, running, or showing some specific emotional state. We use, as a case-study, a scenario capable of offering the necessary resources to the survival of the agents who live there.

Introduction

As an answer to his question: "What sorts of machine can love?" Aaron Sloman (Sloman 1998) suggests an abstract architecture that classifies love and all other emotions in distinct categories and presents the necessary requirements for a machine to feel emotions.

The present work does not offer a definitive reply to Sloman's question. However it aims to raise issues related to the basic requirements in his architecture through the specification of a model of an agent that is strongly inspired in biology: the Physiological Model of Emotions (PME). An agent modelled by the PME shows an intelligent behavior which emerges by intention generators and emotional states.

The Physiological Model of Emotions

The PME has as main objective to model/construct an agent capable of showing an intelligent behavior and not just an "apparently" intelligent behavior, that is, it does not intend to model some of the **effects** of an intelligent behavior, but the underlying **mechanisms** of these effects.

According to (Maturana and Varela 1997), the idea of modeling those effects comes from a physical approach. Physics operates with general rules and does not care about the beings that cause or carry out such phenomena. However, intelligence is a biological phenomenon and therefore it must be treated from a biological point of view, beginning with the generating mechanisms of those effects, trying to evaluate the behavior of each element that gives rise to the phenomenon in an independent form.

Works coming from the neuroscience branch such as (Damásio 1994) show that one of the most important "mechanisms" that composes the phenomenon of the intelligent behavior of men and animals is the emotional state. According to that author, emotional reactions are decisive in the decision-making processes and the basis of his somatic marker hypothesis, where the decision-making is supported by positive and negative answers of the body, acting as inhibitor or stimulator of a given choice.

An agent modeled by the PME also intends to depict an intelligent behavior in accordance to the specifications of the reactive layer of the H-CogAff architecture shown in (Sloman 1998) and (Sloman 2001). This layer presents only primitive mechanisms shared by all kinds of animals. The main feature of reactive mechanisms is their inability to evaluate and select possible future courses of actions. They can merely react to detected situations, no matter if internal or external. Therefore, the PME uses the body as a main generator of intentions and considers a restricted set of emotional states influencing the decision-making. The work is also visibly inspired in D. Cañamero's Abbots (Cañamero 1997). It views and evaluates emotions from a biological point of view, instead of a cognitive one.

The expression "physiological" comes of the fact that the model is strongly inspired in the human being and animal physiology. It tries, if possible, to avoid abstractions that do not resembled the body's functioning. However, from a physiologic point of view, a detailed model means a very complex one. For pragmatic reasons it is important that this model presents, at least in this first stage, some level of abstraction.

According to (Guyton and Hall 1998) the human body is a social order of 75 to 100 trillions of cells organized in diverse different functional structures, where the most

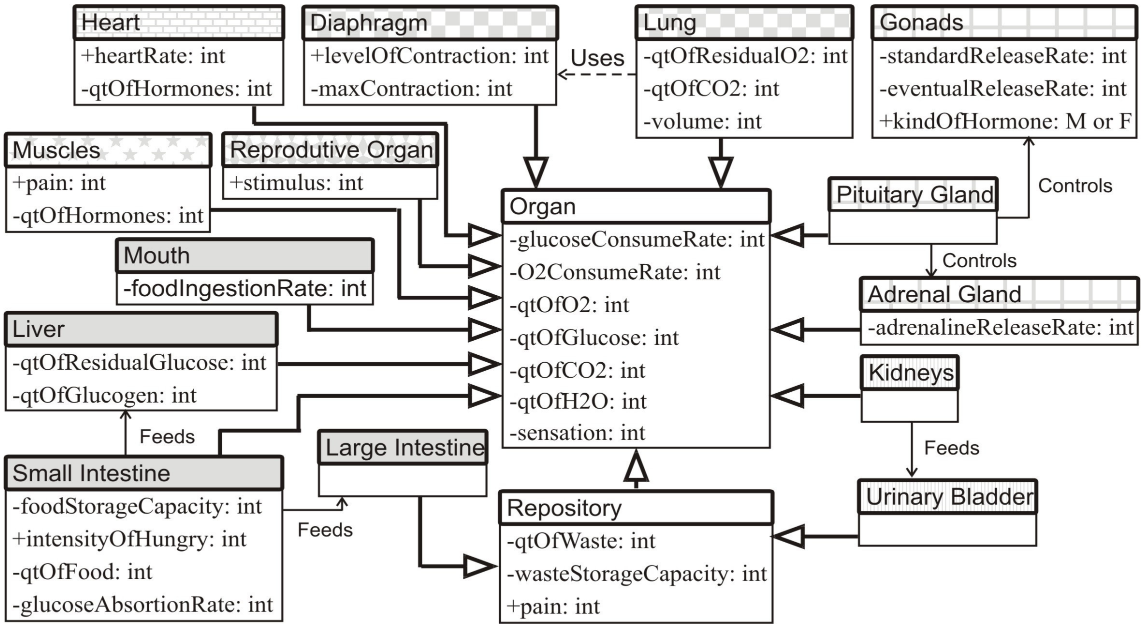

Figure 1 – Body's conceptual diagram (arteries and veins not included).

important structures are called organs. Each internal functional structure or organ has a role in the maintenance of the internal environment. Thus, it is easy to perceive that to model the functioning of each cell individually is a very complicated task. Even with certain level of abstraction, the task of modeling the functioning would be complex and costly from the computational point of view. This is exemplified by the proposal of D. Harel (Harel 2002). He estimates at least 10 years of work by many groups with diverse backgrounds to construct a full, true-to-all-known-facts 4-dimensional model of the *C. elegans* nematode worm. And this is possible only because the worm is transparent, its cell lineage is invariant, and the total number of cells is relatively small. However, a reasonable alternative would be to detail the functioning of each organ or tissue formed by these sets of cells.

In the PME the idea of a cell gave place to a set of cells forming organs or tissues and, therefore, all the activities carried out by each cell are summarized in the functioning of the organ or tissue of which it is part. Each one of these organs and tissues has an important role in the homeostasis of the body, either supplying or generating products for it.

One of the most important concerns of the PME is exactly the emotions, or how an agent modeled by the PME shows these emotions. One problem faced is the high number of controversies about emotions. For instance, (deSousa 2003) shows the enormous diversity of approaches for this subject, both for the "psychological" and for the "biological" one. Since the PME follows a biological approach, the emotions were also tackled from the biological point of view. The model is based on the idea which appeared in (Ledoux 1996): a limited number of emotions do, in fact, have significantly different manifestation in the body. The great variety of emotional states is obtained by the interaction of these states with cognitive aspects. The real interest of the PME is the set of inherent primordial emotions (plus its physiological manifestation).

An agent that is concerned with how to obtain food, to flee from enemies, and to find sexual partners does not need to pursue rich philosophical aspirations. Also, it does not require *complex* emotional states such as envy or guilty. For these reasons some emotions are unnecessary. Besides, this kind of emotion does not belong to the first layer of the H-CogAff architecture. The emotional states from the first layer are denominated by Sloman as primary emotions. These are primitive emotional states like being startled, terrified, sexually stimulated, etc.

The Implementation of the PME

The initial concern of our work was the theoretical basis of the PME, e.g. how to include the work of the diverse researchers that had served as basis for it. In its current stage, the model already possesses a complete specification of the intentions generator of the body, as it is shown in Figure 1.

As a simplified model of an organism, the PME includes only a restrict group of organs and tissues which were found to be necessary to the basic functioning of the body. For example, (Guyton and Hall 1998) point that the lymphatic system is an accessory path where the bodily liquids flow from the interstitial space back to the bloodstream, avoiding stagnation among cells, since the veins cannot do it by themselves. However, if the proposed model has not liquid among cells (and this is the case here since it has no cells at all) all main functions of the lymphatic system become of little use. Thus, the systems which remained in the PME are:

- **Respiratory system:** responsible for carrying oxygen from the air to the blood stream and expelling the waste product of carbon dioxide;
- **Digestive system:** where the nutrients (in this case glucose) in absorbed and the waste is disposed;
- **Endocrine system:** this is very important to emotional reactions and sexual behavior;
- **Circulatory system:** effectively, carries oxygen, carbon dioxide, glucose and hormones through veins and arteries to all the organs of the body;
- **Urinary system:** where the kidney makes up a filter system for the blood and sending waste (urine) into the bladder for storage until it can be disposed;
- **Nervous system:** crucial in the control of the systems above.

The range of possibilities opened with this small set of organs and a body becomes very interesting. After all, each organ acts as an intention generator, since it needs oxygen and nutrients to work. The absence of any substrate makes the organ work improperly, generating different stimuli to the nervous system. Moreover, the circulatory system, through the vasoconstriction and vasodilatation of the arteries, is constantly modifying the amount of substrata sent to the organs and tissues, due to the variations in the bloodstream caused by the alteration in the cardiac beatings. Different physiological states appear when the organism is eating, running, or showing some specific emotional state.

The model was designed with two types of primordial motivations: Survival and sexual motivations. The first type of motivation comes from the idea that all organs of the body need energy to work correctly, and to carry out its functions in the homeostatic balance. Therefore, this organism is interested in the production of energy to keep himself “alive”.

As a real organism, every organ of the PME needs ATP (*adenosine triphosphate*) to work. According to (Guyton and Hall 1998) this ATP is obtained through the chemical reaction of the oxygen with three different types of foods: glucose derived from the carbohydrates, fat acid derived of the fats, and amino acid derived from proteins. However, most of the ATP is gotten from glucose. Then, again for the sake of abstraction, the agent is only interested in getting glucose, so that together with the oxygen it can generate ATP. A part of the model was then specified in order to get and distribute O_2 and glucose through the organism, to eliminate resultant CO_2 and H_2O of the attainment reaction of the ATP and to consume this last one. This process involves mainly the respiratory, digestive, circulatory and urinary systems.

The sexual motivations are presented in a very simplified form and only act as a secondary intention generator. They are related to the endocrine system, which is responsible for the production of testosterone and estrogen, the two sexual hormones incorporated in the model.

In summary, the PME offers the possibility of simulating a body with several organs, working in the same time scale, constantly generating different stimuli in order to keep a homeostatic balance, as well as a set of emotions acting directly on the physiology of this body in order to influence the decision-making.

A Brain to Control Everything

The specification of the body is only the first step of the PME. Apart from this, it is necessary to define or model a brain that deals with the information sent by the body. This is so because a body would be useless if the central control of this organism were carried out by a completely reactive brain. The strategy of control adopted in the Physiological Model of Emotions is the theory of Neuronal Group Selection (TNGS) or Neural Darwinism proposed by G. Edelman (Edelman 1992). This theory seeks to explain the functioning of the mind from a biological point of view, relating the behavior of neurons to the behavior of the immune system: a repertoire of antibodies constitute a population which is selected up and down according to the presence of viruses and other threats.

It is important to say that the brain of the PME needs to deal with two concurrent environments. The external one (where the agent is immersed), and the intern environment of the agent proper. Thus, there is a number of perceptions to evaluate. The next step is the creation of distinct networks of perception: e.g. one for the "*hypothalamus*" (to receive stimuli from the body) and a species of "*cortex of external perception*" (to deal with the external stimuli).

Although a reactive brain is not desired in the model, at the neural level reactive processes do occur: this is the basis of the value system proposed by Edelman. Values are phenotypic aspects of an organism that were selected during evolution such as the synaptic changes that occur during brain development and experiences. For example, babies grasping objects is a skill developed after trying random movements and receiving positive and negative feedback. This enhances the selection of synapses and groups of neural patterns of activity that lead to appropriate actions. For the PME, such a value system is needed to model the implementation of the physiological manifestations of emotions, since these need to be triggered in specific situations.

Obviously we are aware of the difficulties posed by both the modeling of the body and the brain. The difficulties associated with the former were already pointed out (Harel 2002). As for the latter, which are even more challenging, the work of Edelman and colleagues on the Darwin III and IV artifacts (Edelman and Tonomi 2000) proves that simple value systems are capable of real-world behavior. Darwin IV is an artifact which has "`eyes'' to track randomly moving targets. Its value system has an inherited bias that states that "light is better than darkness'', i.e. Darwin IV has a taste for light. Neuronal groups which leads to choice of, say light objects, are selected up and so Darwin IV is able to pick up light objects and reject dark ones.

Although it is still a huge step to get artifacts like Darwin IV to realize more sophisticated interactions (e.g. those related to the various emotions), values and emotions are coupled and are central to conscious experience (Damásio 1994, Edelman and Tonomi 2000). Thus, any step in this direction, no matter how small, is worth.

Case-Study

We intend to use the PME in a well-know scenario like the Gridland (Cañamero 1997), a bi-dimensional grid capable of offering the necessary resources to the survival of the agents who live there: oxygen and food sources with glucose. The choice of the scenario was motivated by the similar aims of the two works, that is, the attempt to analyze emotions on neurobiological and evolutionary perspectives. The PME also seeks to depict the physiological manifestations of emotions in the organism, as acceleration of the cardiac beating, vasoconstriction and vasodilatation, and release of hormones in the bloodstream. This makes the creature depict different internal and external perceptions, directly modifying its behavior.

The main difference between a PME's agent and the Abbots lies in the internal milieu. The internal milieu of the Abbots is constituted by a set of "*bodily states*" which can be of two types – "*controlled variables*" and "*hormones*". The first one are variables necessary to the survival of the creature, controlled by homeostatic processes which keep them in certain range of stability. The second type, the hormones, are released when the Abbot have an emotional reaction. Each hormone can affect several variables, but it has a particular valence with respect to each of then.

The PME's internal milieu is not composed by a set of variables, but by a group of objects, which could do more than just change their current state. The main advantage of a group of objects consists in the fact that it can be expanded and each detail refined. The PME just proposes the basic structure, the main idea. In a first version, the PME's brain sends a message to the muscle (object) to act. In the future these muscles could be divided in a set of specific muscles (set of objects), surrounded by a neurosystem sending and receiving information about every stimulus between objects and sets of objects. This applies not only to the muscle but for all other entities in the model.

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