Evolving an Artificial Homeostatic System

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Abstract – Theory presented by Ashby states that the process of homeostasis is directly related to intelligence and to the ability of an individual in successfully adapting to dynamic environments or disruptions. This paper presents an artificial homeostatic system entirely under evolutionary control, composed of an extended model of the GasNet artificial neural network framework, named NSGasNet, and an artificial endocrine system. Mimicking properties of the neuro-endocrine interaction, the system is shown to be able to precisely coordinate behaviour for an agent with internal dynamics, which should explore the scenario without endangering its essential organization. It is envisaged that the proposed framework is a step towards the design of a generic model for coordinating more complex behaviours and potentially coping with severe disruptions.

Keywords – Artificial Homeostasis - Evolutionary Artificial Neural Networks - Robot Autonomous Navigation

1. Introduction

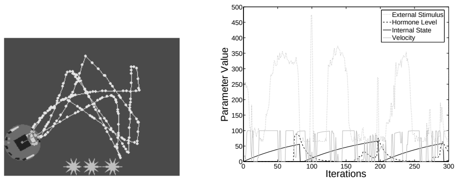
The term *homeostasis* has its origins in the work of the French physiologist Claude Bernard (1813-1878), who founded the principle of the internal environment which was later expanded by Cannon in 1929 as the process of homeostasis [2]. Nonetheless, for Pfeifer & Scheier [7], homeostasis was completely defined by the English psychiatrist William Ross Ashby in 1952 [1]. For Ashby, the ability to adapt to a continuously changing and unpredictable environment (adaptivity) has a direct relation to intelligence. During the adaptive process, some variables need to be kept within predetermined limits, either by evolutionary changes, physiological reactions, sensory adjustment, or simply by learning novel behaviours. Therefore, with this regulatory task attributed to the homeostatic system, the organism or the artificial agent can operate and stay alive in a viability zone.

Basically, homeostasis can be considered paramount for the successful adaptation of the individual to dynamic environments, hence essential for survival. Moreover, Dyke and Harvey [4] have pointed out that in order to understand real or artificial life it is necessary to first understand the conceptual framework and basic mechanisms of homeostasis. In the human body some particular sensory receptors trigger specific responses in the nervous, immune and endocrine systems, which are the main systems directly related to the process of homeostasis. Therefore, one can say that it is a consensus that homeostatic processes are strictly connected to the balance of any real or artificial life.

The theory presented by Ashby have motivated applications of homeostasis in the synthesis of autonomous systems in mobile robotics [3][9][6]. The ideas presented by some researchers, like Di Paolo [3], encompass homeostasis within one unique structure, i.e. an artificial neural network (ANN) capable of dynamically changing their connection plasticity rules. Our present work goes in a different direction and is an extension of a previous work by Vargas et al. [9] and Moioli et al [6]. In the homeostatic system developed here the entire artificial homeostatic system (AHS) is under evolutionary control. An artificial endocrine system (AES) is synthesized by means of evolution and is responsible for controlling the coordination of two evolved spatially unconstrained GasNet model [5], named non-spatial GasNet (NSGasNet) [8]. Therefore, we are proposing a further step in the design of an evolutionary artificial homeostatic system (EAHS).

2. Proposal

Like the previous work by Vargas et al. [9] and Moioli et al. [6], this research is particularly concerned with neuro-endocrine interactions. The endocrine system employs chemical substances, called hormones, to maintain homeostasis, metabolism and reproduction. The release of hormones can also affect the nervous system, which in turn can transmit nerve impulses affecting the production and se-



(a) (b)

Figure 1. Trajectorie (a) and EAHS variables (b)

cretion of hormones, thus establishing a control loop mechanism. There are positive and negative feedback mechanisms represented by coupled difference equations, which are reminiscent of the biological neuro-endocrine systems interaction.

The new evolutionary artificial homeostatic system (EAHS) is composed of an artificial endocrine system (AES) and two NSGasNet models. Our work proposes not only the evolution of both NSGasNets, but also the AES, aiming at developing a more robust architecture of an EAHS.

3. Results

The experiment starts with a robot exploring the arena, controlled by the obstacle avoidance network. The AES was designed to sense the internal state of the robot. If the internal state grows above 90, in a 0 to 100 scale, the robot is considered to be dead. To obtain a successful performance the robot should be able to efficiently switch between exploration behaviour and phototaxis behaviour. This switching is expected to be due to the production of the hormone related to the decrease of battery level. After the recharge of the battery (associated with being close to the light), and consequently the decrease in the related hormone level, the robot should return to its original behaviour of exploration.

When the hormone level increases, the robot stops exploring the scenario and starts chasing the light. This confirms the influence of the hormone level over the robot's autonomous behaviour. During the experiment, the robot traverses the arena in maximum speed, only adjusting its speed when avoiding collision courses or when changing the behaviour to phototaxis.

4. Conclusions

This work is a step forward in the design of an evolutionary artificial homeostatic system (EAHS). Towards the goal of creating an even more robust system, this work has introduced an artificial homeostatic system which is entirely under evolutionary control. It consists of two evolved artificial neural networks coordinated by an artificial endocrine system. The ANNs followed the model proposed in Vargas et al. [8], drawing inspirations from gaseous neuro-modulation in the human brain. The objective was to design a more biologically-plausible system inspired by homeostatic regulations pervasive in nature, which could be able to tackle key issues in the context of behaviour adaptation and coordination.

Future work would include deeper analysis of the neuro-endocrine interactions, eventually adapting a framework aimed at the coordination of more complex sensorimotor behaviours.

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