A Neural-Endocrine Architecture for Foraging in Swarm Robotic Systems

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Overall Vision

Long-term autonomy

We are attempting to build robotic systems that are capable of extended autonomy (numerous weeks), when deployed in systems at sea. Key to this is the idea of "homeostasis". Our end-point for this project is a collection of ocean-going robotic surveillance systems.

Homeostasis

The tendency toward a relatively stable equilibrium between interdependent elements, esp. as maintained by physiological processes. (Dictionary)

But first ...

We need to design an architecture that is capable of affording such autonomy, one step at a time. In this work, we examine the role of our architecture for the co-ordination of a swarm of robots : land-based.

Our Approach

- Inspired by Neuroendocrinology
- Combined neural network with artificial hormones [1, 2]
- General architecture is akin to a behaviour based approach, though the implementation is very different from that of a subsumption architecture
- Define a series of neural networks for certain behaviours, that are "moderated" via artificial hormones, that allow for "switching" between behaviours
- Developed quite well for a single system, exploring the use here in the context of a swarm of robots (not comparing approaches)

Endocrine System I

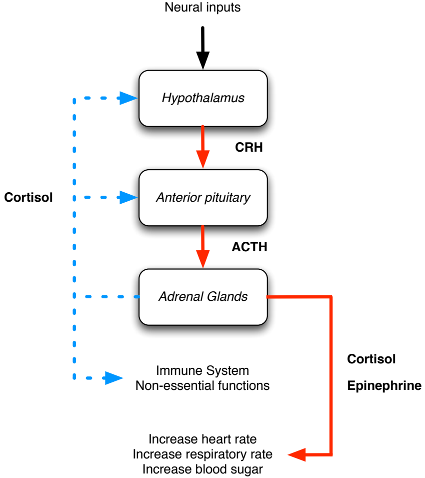
- Two main components:
  - Glands
  - Hormones
- Glands:
  - Multiple types of gland are distributed throughout the human body
  - Each gland is responsible for the production and control of a particular type(s) of hormone
- Hormones:
- Hormones are a chemical substance that has a specific regulatory effect on the cells upon which they act
  - Therefore, they can affect behaviour
- They are produced not only by the endocrine system, but also the neural and immune system
- Production of hormone is linked to changes in state of the organism

Endocrine System II

- Usually a number of hormones in the body at any one time
- Binding takes place between hormones and cells (at the receptor level)
    - Receptors are located either within the cell nucleus or the plasma membrane (this depends on type of hormone the receptor is for)
    - Many may bind at the same time, giving rise to a complex interaction of many components!
- Hormones typically decay over time
    - Minutes or days

Neuroendocrine Example

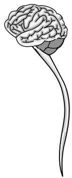
- The Stress Response
- HPA-axis
- CRH-ACTH-Cortisol sequence
- Prepares the body for stressful situations
- Long-loop negative feedback



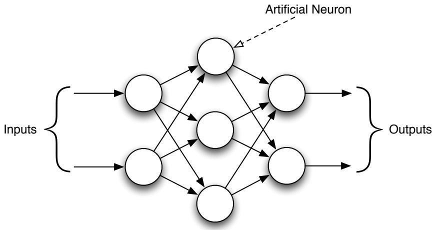
What do we want from our system?

- Allow for the construction of a collective system that performs foraging
- Examine the scalability of the NE architecture
- Understand which behaviours to include in the NE architecture, which not too.

Neural-Endocrine Control Architecture I

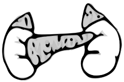


Central Nervous System

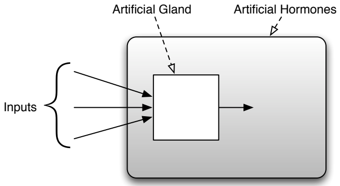


Artificial Neural Network

$$u = \sum x_i w_i$$
$$y = f(u)$$



Adrenal Glands and Pancreas



Artificial Endocrine Gland

$$c_g(t) = R_g(t) + \beta_g c_g(t-1)$$
$$R_g(t) = A(x_i \ldots x_n)\frac{\alpha_g}{1 + c_g(t-1)}$$

c_g : hormone concentration

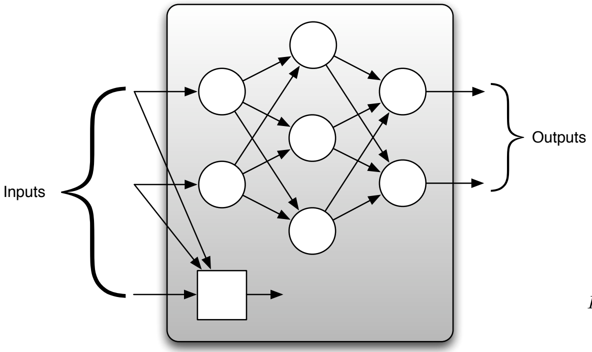
R_g : amount secreted

β_g : decay rate

A : stimulation function

α_g : stimulation rate

Neural-Endocrine Control Architecture II

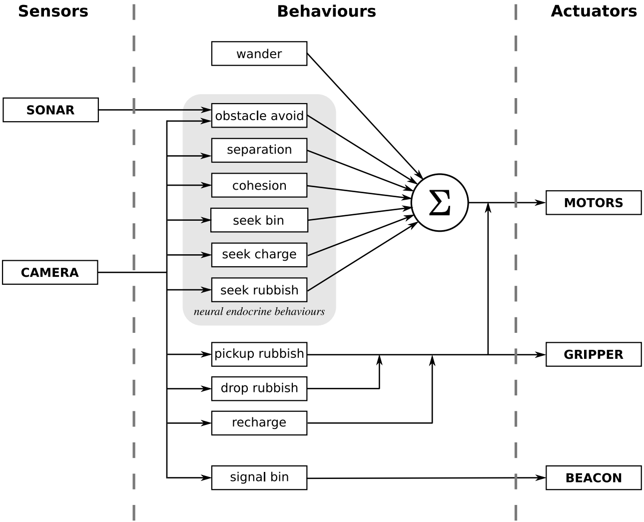


Artificial Neuroendocrine Network

$$u = \sum x_i w_i \sum c_g s_{ig}$$
$$y = f(u)$$

$$c_g(t) = R_g(t) + \beta_g c_g(t-1)$$
$$R_g(t) = A(x_i \ldots x_n) \frac{\alpha_g}{1 + c_g(t-1)}$$

Control System Overview



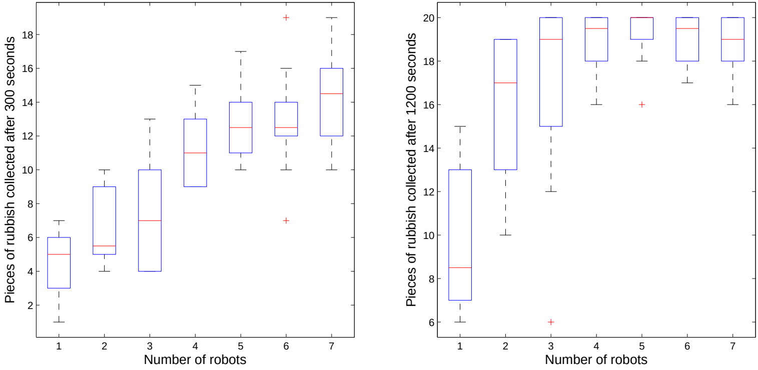
Experimental setup: Foraging Robots

- 2 different environments
- 1..7 robots
- 10 initial configurations of randomly distributed rubbish
- 2 * 7 * 10 = 140 simulated runs
- 20 minute time limit

Foraging Robots: “Proof by Video”

(Video not included)

Results



(a) (b)

Figure: Graphs showing the number of pieces of rubbish collected over periods of 300 (a) and 1200 (b) seconds, with varying numbers of robots between one and seven: World 1

Summary

- Presented a simple NE architecture for foraging
- NE architecture maps well onto this type of domain
- Further work is to take onto oceangoing platform - initial trials with NE architecture here are promising - here we focus on power management issues.

M. Neal and J. Timmis.
Timidity: A Useful Mechanism for Robot Control?
Informatica, 27(4):197–204, 2003.

M. Neal and J. Timmis.
Recent Developments in Biologically Inspired Computing, chapter Once More unto the Breach: Towards Artificial Homeostasis, pages 340–365.
Idea Group Publishing, 2005.