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Endocrine Inspired Modulation of Artificial Neural Networks to Aid Survivability in Mobile Robotics

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The desire to operate highly autonomous robots in harsh conditions which may threaten their survival has demonstrated the need for artificial systems which can adapt to their environment. Traditionally many have attempted to control robots with artificial neural networks (ANNs). These provide reasonably successful instantaneous reactive behaviours in response to stimuli (e.g. correcting course deviations). However they lack the ability to respond in a longer term fashion to more gradually changing conditions. The same problem is true in biology, especially with regards to species without any higher brain functions that are able to consider longer term factors. In mammals two other systems play a key role in longer term changes to the neural system, the endocrine and immune systems. The endocrine system is able to modulate the behaviour of a variety of cells (including neural cells) with a time frame lasting between a few seconds and several months. Whereas the immune system provides longer term responses lasting between minutes and years. However, the immune system is far more complex than the endocrine system and its capabilities vary dramatically between species, therefore it will not be dealt with here.

The endocrine system provides a decentralised, low latency, low bandwidth, broadcast messaging system. It operates through several glands which secrete chemical messengers, known as hormones into the bloodstream. As these flow through the bloodstream they reach virtually all cells in the body. However, cells will only be affected by hormones for which they have binding receptors. Upon binding to a cell's receptor a hormone will either suppress or enhance a particular behaviour of that cell. The binding affinity between a given cell and a particular hormone depends upon the quality of the fit between the receptor and the hormone. The release of hormone from a gland can be triggered by a number of events including other hormones, immune responses or neural signals. A hormone release can trigger behaviour changes within seconds, however the body may continue to release hormones for months at a time.

Computer scientists have for some time experimented with artificial endocrine systems that are able to modify the behaviour of an artificial system. For example Arkin (1992) [1] employed artificial endocrine systems to manage energy consumption, releasing hormones to signal that energy was available for use. This is analogous to insulin, which the endocrine system secretes when blood glucose levels are high in order to trigger the absorption of glucose from the bloodstream. More recently Neal and Timmis (2003) [2] and Mendao (2007) [3] have taken a further step in modulating the behaviour of artificial neural networks with an artificial endocrine system. In their work the hormone signals trigger a change in the weights of each affected neuron. This allows the probability of a given neuron firing to be decreased or increased, thus suppressing or promoting a particular behaviour. This work has demonstrated the possibility of gradually switching between behaviours and balancing out competing behaviours.

There are several potential advantages of a neuro-endocrine controller over other modulation techniques intended for ANNs. The rapid and global nature of hormone diffusion allow for rapid modulation of a wide range of behaviours, across both neural and non-neural systems. This is highly desirable in situations threatening survival (as experienced by a robot operating in a harsh environment). However, in addition to short term reactions an endocrine controller allows for longer-term modulation taking place over a period lasting between several days and months. Such properties are helpful in performing resource management and the resolution of conflicting demands, which in turn are highly beneficial in improving a robots ability to autonomously preserve itself in harsh conditions. From an implementation point of view the artificial neuro-endocrine system is both computationally simple and decentralised. This favours the use of simple, low cost and low power consumption computers arranged in a distributed and fault tolerant manner.

In order to test the neuro-endocrine controller in genuine survival situations a small (3.5 metre long) sailing robot[4] has been developed. This provides a low cost and potentially energy-autonomous test case. It is intended to remain at sea for several months while performing ocean monitoring. It will be required to deal with the competing demands of gathering data, regulating battery levels and avoiding or fleeing from dangerous situations. The current controller implementation consists of a traditional multi-layer perceptron for sail and rudder position control with respect to current heading and wind direction. This is in turn modulated through an endocrine system which is responding to the availability of energy from batteries and solar panels.

References

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