EMBODIED SIMULATION OF ANIMAL BEHAVIOUR; A WAY TOWARDS INTELLIGENT ENGINEERING DESIGNS

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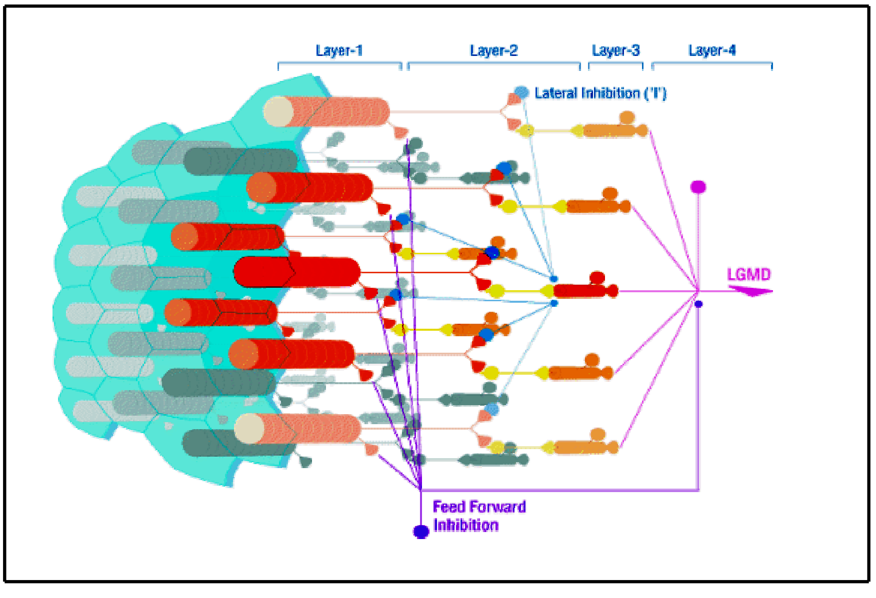
SUMMARY

Objectives

The project aims to analyse ways by which simulation of biological neural systems may lead to intelligent engineering designs.
Specifically, we investigate the role of lateral inhibition in the context of locust collision detection.
The experiment consists of designing natural – like visual stimuli for a small mobile robot and testing its behaviour in the presence and absence of lateral inhibition between the input neurons within its control circuitry.

Context

Traditionally robotic technology has involved active sensors, such as ultrasound and infra – red devices, or high – precision sensors, such as laser scanners, for the detection of obstacles.
In biology, however, many examples are found of systems which rely on visual information to accomplish this task, and these have been successfully applied to real world robotic control tasks. Neurons tuned to approaching objects have been identified in species such as the locust.
The Lobula Giant Movement Detector (LGMD), a large visual interneuron in the optic lobe of the locust is one such neuron (***Fig.1***).



(Fig.1)

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A neural network model of the input circuitry of the LGMD has been constructed with three principal layers:

- The input photoreceptive layer, which responds to changes in the image in order to detect the edges of moving objects;
- A processing layer, where excitation passes retinotopically through the network while delayed inhibition spreads laterally;
- The output layer, which represents the LGMD, and where the excitation and inhibition are combined.

In addition the feed – forward pathway, which inhibits the output of the model LGMD during large changes in the image.

This model displays the same preference for approaching objects as the LGMD and reveals that, at least for simple stimuli, this preference results from a critical race between the excitation produced by the movement of an object's edges and the delayed lateral flow of inhibition within the network.

Inhibition spreads laterally between neurons within a layer and is known as lateral inhibition. Lateral inhibition is already known as a mechanism for sharpening the receptive field of a neuron, so that it responds well to small stimuli on its own receptive field, but not to large stimuli that fall on the receptive fields of many neurons. We explore additional roles for lateral inhibition.

Methods and results

The experiments are conducted in a simplified arena using a Khepera mobile robot (K-Team A.G., Lausanne, Switzerland). The arena is surrounded by a white cardboard perimeter wall. Objects are placed around the arena's edge for the network to detect and avoid. Within this environment the sensor copes with shadow and contrast effects. The robot's behaviour is tracked from above using a digital video camera in conjunction with the IQR421 tracking system, and is being testing at a variety of speeds of movement.

The IQR421 (Verschure, 1997), is a sophisticated software system allowing the user to precisely model neural networks. Its chief advantage is that is allows cells with realistic, neuronal properties to be modelled and these can be easily altered by the experimenter. It permits the model network to be interfaced with the Khepera mobile robot (K-Team A.G., Lausanne, Switzerland).

The serial communication protocol allows the complete control of the functionalities of the robot through an RS232 serial line. The interface module converts the RS232 line into the S serial line available on the robot. The communication between the host computer and the Khepera robot is made sending and receiving ASCII messages. In all communications, the host computer plays the role of master and the Khepera robot the role of slave. All communications are initiated by the master.

The major challenge is to test the functionalities of the Khepera robot, under the absence and presence of lateral inhibition, in the real world. The real visual environment is dynamic in many respects. Light intensities change, shadows form, clouds move, all of which are not accurately represented by artificial looming stimuli.

It has been shown that the dendrites of the LGMD neuron are covered with input synapses, probably from neurons that originate in the medulla. Each neuron that synapses with the LGMD also synapses with its neighbours; in other words the neurons that drive the LGMD are reciprocally coupled to each other. These microanatomical circuits provide a route for local lateral inhibition among the elements that excite the LGMD, which is a key feature of the input circuitry to the LGMD, allowing it to filter out approaching objects. In the lamina the lateral inhibition between cartridges serves a different function – to sharpen the detection of edges in the image. The way in which the LGMD filters out the image of an approaching object can be envisaged as a kind of race between excitation and inhibition of the units in the medulla that synapse with the LGMD. The excitation

comes from photoreceptors that are stimulated sequentially by the edges of the image as it travels over the eye; and the inhibition travels laterally between the medulla units. As the number of excited units increases, the strength of the lateral inhibition also increases.
The software package associated with the Khepera robot is under reconstruction, using a high – level programming language such as C++.

Significance

The analysis of the simulation results will help in establishing the role of lateral inhibition in the locust system and in the design of efficient collision detection mechanisms for artificial systems.
Development of a smart sensor based on the LGMD would provide a robotics engineer with a compact, safe, low – power solution for obstacle detection using vision, eliminating the need to use traditional image processing methods or active sensing, as for example laser scanners.

References

[1] Peter Simmons & David Young, *"Nerve Cells and Animal Behaviour"*, (1999) 2nd edition.
[2] F.C.Rind, P.J.Simmons, *"Seeing what is coming: Building collision sensitive neurons"*, Trends in Neurosciences, 22(1999) 215 - 220.
[3] M.Blanchard, F.C.Rind, P.F.M.J Verschure, *"Collision avoidance using a model of the locust LGMD neuron"*, Robotics and Autonomous Systems (2000) 17 – 38.
[4] H.R. Everett, *"Sensors for Mobile Robots: Theory and Application",* A.K. Peters, Wellesley. M.A. , 1995.
[5] J.M. Blanchard, *"Collision avoidance: A biologically inspired neural network for the detection of approaching objects"*, Ph.D. Thesis, Faculty of Medicine, University of Newcastle Upon Tyne, UK, 1998.
[5] K – Team, http://www.k-team.com
[6] Newcastle Upon Tyne University Library, http://www.ncl.ac.uk/library/ejs/ejshome.html