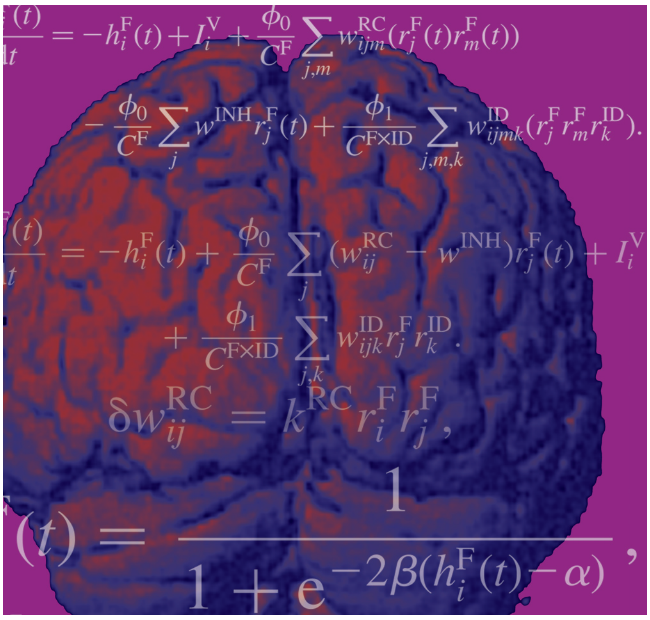
OFTNAI NEWS

Newsletter - Summer 2008

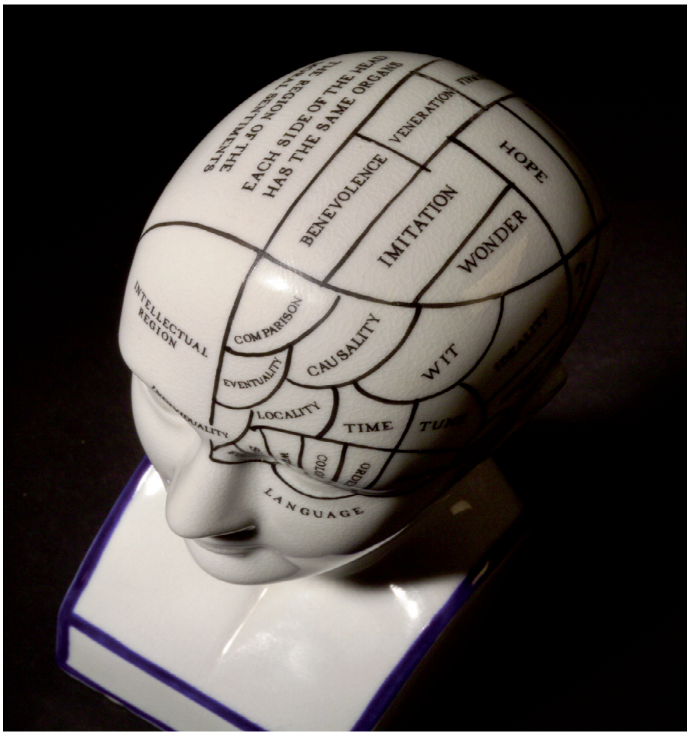
Oxford Foundation for Theoretical Neuroscience and Artificial Intelligence

Discovering how the brain works is perhaps the most extraordinary scientific challenge of our time. Advances in understanding the brain will inform medical research into new treatments for neurological disorders, as well as lead to powerful new techniques in artificial intelligence and robot control. To meet this challenge, our foundation is raising funds to support a new Centre for Theoretical Neuroscience at Oxford, which will be dedicated to teaching and research in computer modelling of the brain. The Centre is currently based within the Oxford University Department of Experimental Psychology.



Over the last year, we have made important contributions to understanding various areas of brain function, including for example:

- How do our visual systems learn to make sense of complex visual scenes? In particular, how are we able to learn to recognize individual objects even if they are always seen in natural scenes with other objects present? Our Centre has recently shown through computer simulation how this task may be accomplished by the brain.



- How do we learn to navigate within our 3-dimensional spatial world? Neurons have been found in the brain that provide information about our head direction, position in the environment or where we are looking. We have continued to investigate how these spatial neurons may develop in the brain as a basis for movement and navigation.

- How is our behaviour shaped by rewards and punishments? In particular, how can the brain learn the best response to make in certain situations if, during learning, we are situated in real-world environments with many things happening simultaneously? This remains an important area of interest for us.

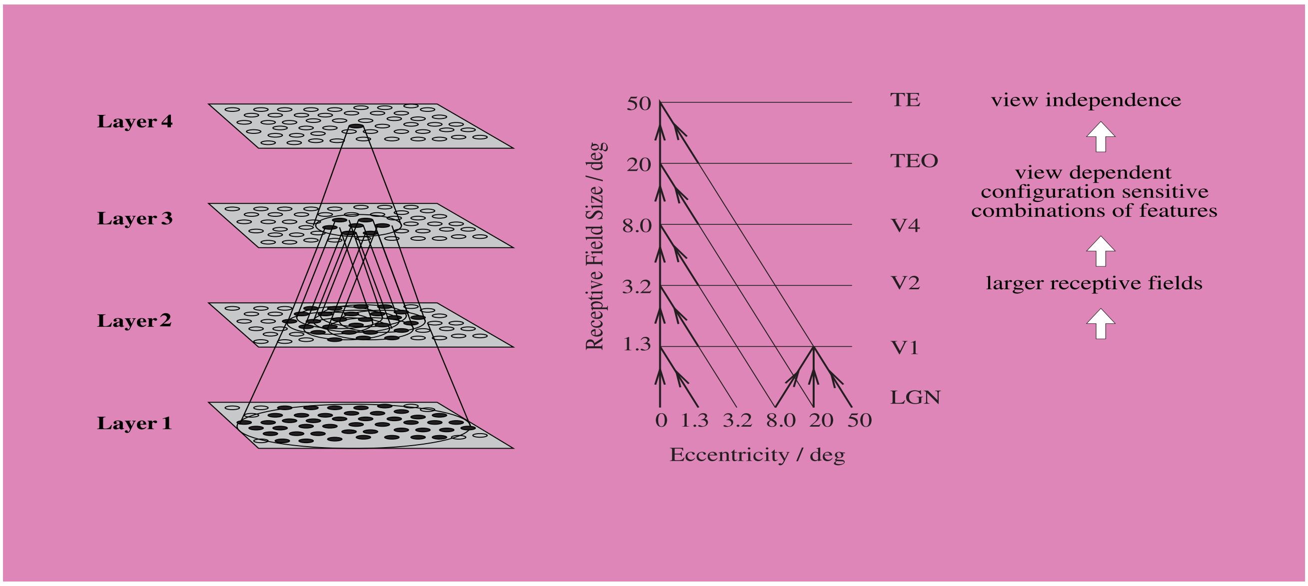
This year our foundation is providing support for training studentships within the Centre, contributing towards the costs of new computers for simulation work, and is the official sponsor of the 11th Neural Computation and Psychology Workshop at Oxford. Let us tell you a bit more about one of our areas of research over the last year: understanding how vision works in the brain.

Focus on understanding vision

A key area of interest for our research Centre at Oxford has been to explain how our visual systems are able to learn to recognize objects and faces from different viewpoints or locations. This is a fundamental question for understanding how vision works in the brain. Although this may at first appear an easy task, this is only because our own brains solve the problem for us! In fact, recognizing objects from different views is a difficult and important problem for engineers who design machine vision systems for industrial robots.

Nelson Mandela from two viewpoints

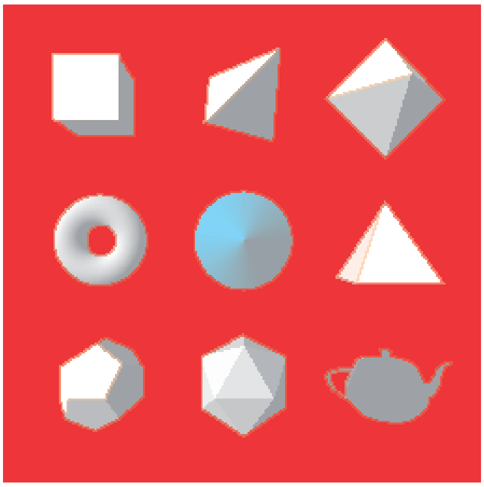
To investigate how the brain solves this problem, we have developed a computer model, VisNet, of visual processing in the brain. The model (shown below) is composed of a series of four layers of neurons, which correspond to successive stages of the ventral visual pathway. VisNet has been shown to be able to learn to recognize objects and faces from any viewpoint or location [1][2].



The VisNet computer model is comprised of four layers of neurons, which correspond to successive stages of processing in the ventral visual pathway: LGN, V1, V2, V4, TEO and TE.

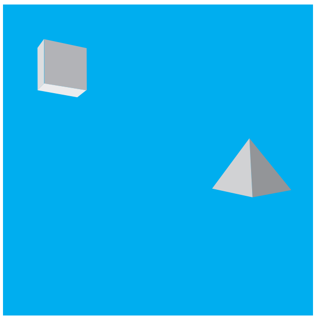
Recent advances: Seeing the trees for the wood

More recently, we have begun to investigate how our visual systems may learn to interpret sensory input from complex real-world scenes. In particular, a major challenge has been to explain how our visual systems can learn to recognize individual objects even if they are never seen in isolation, but are always seen with other objects in natural scenes [3]. That is, how can we learn to see and recognize individual objects such as trees if they are always embedded within a natural scene like a wood? Our Centre has recently made important progress towards solving this problem by incorporating more realistic models of the natural visual environment into the computer simulations. In particular, if objects are seen in different combinations at different times, then this helps the visual system to learn to recognize the objects individually [4][5]. For example, if our computer model, VisNet, is exposed to visual input from many different pairs of objects rotating together, then the network actually learns to recognize the individual objects rather than the pairs of objects seen during training!

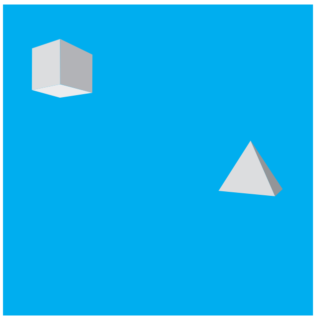


The VisNet computer model receives visual input from a world containing nine individual objects that rotate about their vertical axis.

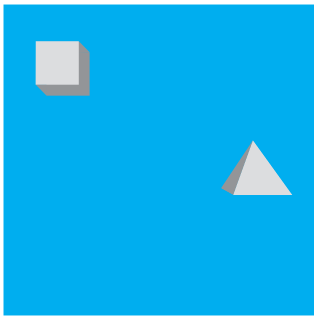
During training, at least two of these objects are always present at a time.



30 degrees



60 degrees



90 degrees

During training, VisNet sees many different pairs of objects rotating together. Here we show a cube and a pyramid rotating together. However, after training VisNet has actually learned to recognize the individual objects themselves!

In more recent work we have shown that if just two objects are always seen together, but they move independently of each other, then the visual system can also learn to recognize them separately. This further breakthrough has been achieved by incorporating a more accurate model of the known neurobiology of the visual system into our computer simulations – i.e. the problem has been solved by carefully mimicking the architecture of the brain. This research has provided a vital insight into how our visual systems develop in natural environments, and is a step towards the development of robot vision systems that can learn to make sense of complex visual scenes.

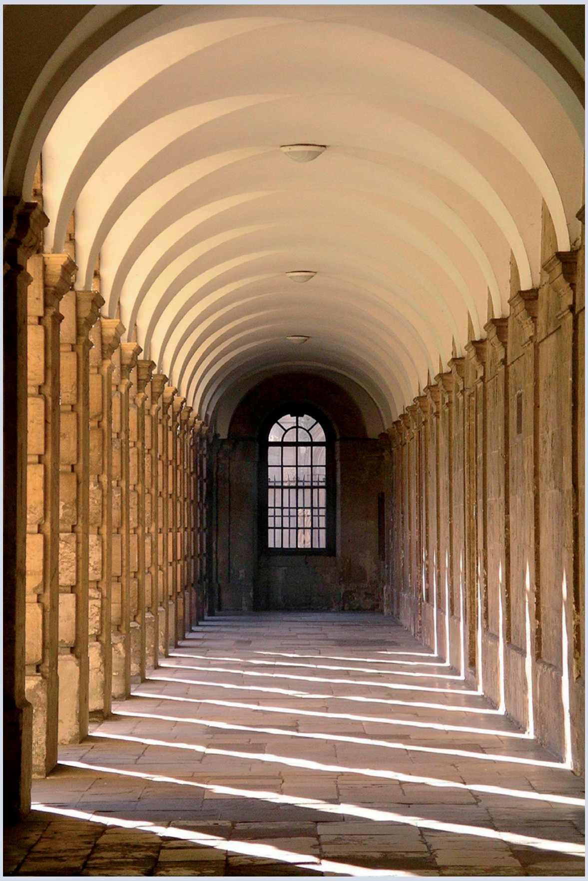
REFERENCES:
[1] Wallis, G. and Rolls, E.T. (1997). Invariant face and object recognition in the visual system, Progress in Neurobiology 51: 167-194.
[2] Stringer, S.M., Perry, G., Rolls, E.T. and Proske, J.H. (2006). Learning invariant object recognition in the visual system with continuous transformations, Biological Cybernetics 94: 128-142.
[3] Stringer, S.M. and Rolls, E.T. (2000). Position invariant recognition in the visual system with cluttered environments, Neural Networks, 13: 305-315.
[4] Stringer, S.M., Rolls, E.T. and Tromans, J.M. (2007). Invariant object recognition with trace learning and multiple stimuli present during training, Network: Computation in Neural Systems, 18(2): 161-187.
[5] Stringer, S.M. and Rolls, E.T. (2008). Learning transform invariant object recognition in the visual system with multiple stimuli present during training, Neural Networks, in press.

Foundation Dinner at Queen's College, Oxford
December 2007

We recently held the first of our foundation dinners for charities and companies interested in Oxford research into computer simulation of the brain. This event took place on Thursday 13th December 2007 in Queen's College, Oxford. During the evening the following presentations were given:

- Dr Simon Stringer discussed why we need to think about the brain as a "complex system" composed of billions of interacting elements, whose emergent behaviour is difficult to predict without the tools of computer modelling. He then described recent advances in understanding how the visual system is able to learn about individual objects even when they are embedded within natural visual scenes.
- Professor Kim Plunkett spoke about computer modelling of language development. He demonstrated computationally that language can only start to take off once verbal and visual descriptions of objects are well-formed. This may explain why the spurt in word use doesn't start until children are around two years of age.
- Professor Edmund Rolls discussed the application of computer simulation to understanding neurological disorders such as Schizophrenia. In particular, he demonstrated computationally how reduced current at certain synapses could result in many of the symptoms of Schizophrenia, indicating where drug research might be focussed.

Everyone enjoyed the first dinner so much that we are now keen to repeat the event on a regular basis!



Our first Foundation dinner was held at
Queen's College, Oxford, on 13th December 2007.

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