

Model Answer: Neural Computing, Question 1.

2001

1.

The Hopfield network (i) may have reached a stable state or attractor, from which it will make no further changes; (ii) it may be caught in a limit cycle in which it will continue to oscillate indefinitely between states as the iterations continue; or (iii) it may wander around chaotically in state space without reaching either any periodic or stable states.

[3 marks]

A fully connected Hopfield network consisting of 100 neurons should be capable of storing about 15 stable content-addressable memories.

[1 mark]

If the stored patterns are orthogonal to each other, or as nearly so as possible (i.e. if the inner product projections of the memories onto each other were minimal, or zero), this would maximize the number that could be stored.

[3 marks]

2.

Neurons' orientation selectivity, size or spatial frequency selectivity, and alternation between inputs coming from the left and right eyes for stereo disparity, are embedded locally within each cubic millimeter of brain tissue in the visual cortex. (Receptive field size varies from the superficial to the deep layers; orientation selectivity varies tangentially to the cortical surface, spanning  $2\pi$  radians over 1 mm; and ocular dominance slabs of about 0.5mm width alternate between inputs from the left and right eyes in the orthogonal tangential direction.) These "hypercolumn modules" of  $1\text{mm}^3$  neural machinery themselves migrate systematically across the global 2D visual field, in their own receptive field map positions. Hence 3 dimensions of neural selectivity mappings are embedded locally within the global 2D retinotopic mapping for position, spanning 5 dimensions altogether.

[5 marks]

3.

The fact that the retina has about 100 times more input channels (photoreceptors) than output channels (fibres in the optic nerve) indicates that far from being just an image transfer device, the retina actively processes, encodes, and summarizes the spatio-temporal and chromatic structure of the dynamical scene. What reaches the brain is already an abstracted description in terms of several dimensions of image processing and analysis. Indeed, it is worth remembering that the eye itself develops embryologically from a collapsed ventricle of the brain; the retina should be regarded as a piece of the brain.

[4 marks]

*Continued...*

4.

Synapses in the brain far out-number neurons: on average there are about 10,000 synapses per neuron. In certain sagittal brain slices, one sees white matter almost completely dominating grey matter. (White matter consists of the myelinated axons that connect neurons; grey matter consists of neuron cell bodies themselves.) Learning and memory formation are believed to be based on the formation of new synapses amongst groups of neurons; drugs that interfere with the synthesis of new connections produce amnesia from the time of the drug's application. There are some 30 different known neurotransmitters, and more than a dozen distinct types of synapses. With some  $10^{15}$  synaptic connections in a human brain, many modifiable based on experiences, it seems reasonable to say that connectivity is the basic computational principle in the brain.

[4 marks]