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JGD

Model Answer: Neural Computing, Question 2. 2001

1.

A Kohonen topological feature map finds the organisation of relationships among patterns. Incoming patterns are classified by the units that they activate in the competitive layer, and similarities among patterns are mapped into closeness relationships in this competitive layer. In a Kohonen feature map, a chain of competitive units can span a pattern space of two or more dimensions by competing with each other to represent specific local neighbourhoods in the (n-dimensional) input space (i.e. particular combinations of input appearing at the n input entry points). Because of the neighbourhood that each competitive unit in the chain has won the right to represent, the chain becomes a space-filling curve that can cover, e.g., 2 or 3 or more dimensions. In this sense the feature map achieves dimensionality reduction.

[4 marks]

The training (or learning) time is significantly less in supervised neural nets, because with the desired answers known and with the relationship between parameters and the error function known, direct feedback can be provided to the parameters or connection strengths within the network so as to optimise its ability to represent the data or the desired pattern classes. Learning in unsupervised networks occurs much more slowly because their variation is blind and the origin of their errors may not be clear. However, the major disadvantage of supervised neural networks is that (besides requiring a supervisor) they are less free in exploring solution spaces and are less able to discover and extract hidden structure in the training data.

[2 marks]

A relaxation network can overcome the mathematical problems associated with non-orthogonal sensory and motor representations.

[2 marks]

2.

Non-orthogonal representations underlie the following biological sensory or motor control systems (any three from this list):

- The semi-circular canals of the vestibular system, which have accelerometers measuring angular acceleration to provide a sense of balance, are inclined in planes at about 105°
- The absorption spectra of visual pigments are non-orthogonal to each other
- Spatial visual receptive field profiles are non-orthogonal (their inner product projections onto each other are non-zero)
- Attachments of skeletal musculature involve non-orthogonal control coordinates
- The muscles that control eye movements are attached on non-orthogonal axes

[3 marks]

Non-orthogonal coordinate systems are difficult to work with mathematically and computationally, because effects are not independent of each other. Necessary control signals become much more complicated, and the meaning of sensory coding variables becomes more difficult to interpret than if the coding primitives were orthogonal to each other. However, none of this seems to matter in neurobiological systems, perhaps because they use maps instead of numerical representations.

[2 marks]

3.
Examples of quantal neural structure (any four from this list):

- Nerve impulse generation (all-or-none spikes)
- Synaptic vesicle release (saccules containing 500,000 molecules of neurotransmitter, all released as one packet)
- Post-synaptic "bumps" that can be observed in the trans-membrane voltage due to the arrival of individual molecules of neurotransmitter
- Trans-membrane voltage quantal fluctuations from gating of individual ion channels
- The reliable sensitivity of dark-adapted retinal photoreceptors to individual photons of light: a person can actually "see" single photons, or dim flashes containing fewer than about a dozen absorbed photons across the retina
- "*Eigengrau*" percepts due to the thermal isomerisation of individual visual pigment molecules, nonetheless perceivable as distinct flashes
- The quantised degrees-of-freedom in the receptive field profiles of neurons and therefore in the dimensions of visual codes

[4 marks]

The study of neurological trauma to the brain gives clues to its modular organisation, and specialisation of function. In particular, its fault tolerance when the damage occurs gradually (e.g. a slowly growing tumour as opposed to a sudden injury) suggests that other parts of the brain can be "recruited" to perform the tasks of the damaged parts. It also reveals the degree to which specific functions (like linguistic abilities) are associated with specific brain regions. Finally, systematic visual illusions (such as the universal geometrical distortions) may reveal how our visual algorithms actually work, e.g. by mechanisms of short-range competition, long-range cooperation, and adaptive resonance.

[3 marks]