Neural Theory and Model of Selective
Visual Attention and 2D Shape
Recognition in Visual Clutter

by

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Abstract

Extensive psychophysical and the more recent neurophysiological data from single cellular recordings suggest that selective attention and memory guided processing are some of the key properties of the primate visual brain that endows it with cognitive visual abilities that have not yet been matched by traditional artificial intelligence nor by the current artificial neural network models of learning and pattern recognition. Most neural network models of object and pattern recognition either ignore the mechanism of selective attention or are based on feedforward processes that ignore the role of the feedback pathways and the established memory, which therefore limits their application to simple visual scenarios.

This thesis proposes a neural theory, Selective Attention Adaptive Resonance Theory, and a neuro-engineered solution to selective visual attention, memory guided processing and illumination invariant recognition of complete (unoccluded) but distorted 2D shapes of 3D objects in cluttered visual images. We propose a family of modulated competitive neural layers and neuroengineering design principles for the design of multi-layered competitive 2-D neural circuits whose stability and success depends on feedforward-feedback interactions. The proposed feedback pathways and the top-down modulatory processes simultaneously supervise and stabilise the circuit dynamics, selectively retune the signal transmission gains and the filtering characteristics of the lower layers to enable unsupervised learning and recognition of 2D shapes obtained from unoccluded 3D objects in cluttered images. We propose neural circuits and networks that are capable of self-regulated attentional learning, selective attention and memory guided processing, autonomous detection of novelty/familiarity, distortion and illumination invariant recognition of familiar 2D shapes of real objects in cluttered images.

We conclude that flexible design principles that are based on feedforward-feedback interactions in a closed-loop real-time competitive neural circuit whose modulatory
mechanisms can dynamically retune the signal transmission gains and the cellular receptive field profiles at various stages of processing overcomes some of the problems and limitations that are faced by the rigid architecture of the current artificial neural networks. The neuro-engineeering design principles, mechanisms and circuits as proposed in the thesis provide a new and robust method for solving some of the most difficult problems in visual object recognition that are currently not well handled by the state-of-the-art artificial neural networks and the more conventional computer vision systems. These design principles also open new avenues for further research into more advanced modelling of cognitive and perceptual real-time artificial neural systems that use selective information processing.