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Title: A motion model based on a recurrent network
Conference: CoSyNe 2009
Date: 2/26/2009

Abstract:
Successful interaction with a dynamical environment requires a neural mechanism for the detection of motion. Current motion models such as the Reichardt detector, the motion energy model, and the gradient model, rely heavily on the neural delays of single cells. It is not clear, however, whether neurons in the motion processing pathway of primates have the temporal organization to support this assumption. Moreover, it is well-known that cortical areas have numerous recurrent connections – a feature that is conspicuously absent from almost all motion models.

We investigated whether a motion model without explicit delay lines, but with recurrent connectivity is a viable candidate for the neural processing of motion. We trained an Elman recurrent neural network (Elman, 1990) to reproduce the recorded response of neurons in area MT of the macaque to a moving stimulus (Krekelberg et al., 2006). After successful training, we probed the hidden and output units of the model network with physiological methods, which allowed us to compare their features with properties of real neurons in the motion processing pathway, and gave insight into how the network solved the complex task of motion processing.

Our first unexpected result was that the output layer of the network not only captured the response dynamics of the motion sensitive cells but also correctly predicted the interaction between stimulus speed and contrast observed in MT (Krekelberg et al., 2006). Second, reverse correlation analysis of the model MT neurons revealed slanted space time response maps that matched the original speed tuning curves of the MT cells. This shows that a non-linear system like our recurrent neural network can behave like a simple feed forward model when probed with single flashes. Third, the hidden units of the neural network had speed tuning, direction selectivity, and temporal response properties comparable to neurons in the primary visual cortex. Finally, we found that the network analyzes the speed of motion by combining transient and sustained units in the hidden layer much like the weighted intersection model proposed by Perrone and Thiele (2002).

We conclude that a recurrent network may indeed be a good candidate for the neural mechanism of motion detection; it incorporates the response properties of feed-forward models, matches known anatomical and functional connectivity, and can account for known imperfections in the percept of motion.

References
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