Title: Coding of multivariate stimuli and contextual interactions in the visual cortex

Abstract: The primary visual cortex (V1) has long been considered the main low level visual analysis area of the brain. The classical view is of a feedforward system functioning as an edge detector, in which each cell has a receptive field (RF) and a preferred orientation. Whilst intuitive, this view is not the whole story. Although stimuli outside a neuron's RF do not result in an increased response by themselves, they do modulate a neuron's response to what's inside its RF. We will refer to such extra-RF effects as contextual modulation. Contextual modulation is thought to underlie several perceptual phenomena, such as various orientation illusions and saliency of specific features (such as a contour or differing element). This gives a view of V1 as more than a collection of edge detectors, with neurons collectively extracting information beyond their RFs. However, many of the accounts linking psychophysics and physiology explain only a small subset of the illusions and saliency effects: we would like to find a common principle. So first, we assume the contextual modulations experienced by V1 neurons is determined by the elastica model, which describes the shape of the smoothest curve between two points. This single assumption gives rise to a wide range of known contextual modulation and psychophysical effects. Next, we consider the more general problem of encoding and decoding multi-variate stimuli (such as center surround gratings) in neurons, and how well the stimuli can be decoded under substantial noise levels with a maximum likelihood decoder. Although the maximum likelihood decoder is widely considered optimal and unbiased in the limit of no noise, under higher noise levels it is poorly understood. We show how higher noise levels lead to highly complex decoding distributions even for simple encoding models, which provides several psychophysical predictions. We next incorporate more updated experimental knowledge of contextual modulations. Perhaps the most common form of contextual modulations is center surround modulation. Here, the response to a center grating in the RF is modulated by the presence of a surrounding grating (the surround). Classically this modulation is considered strongest when the surround is aligned with the preferred orientation, but several studies have shown how many neurons instead experience strongest modulation whenever center and surround are aligned. We show how the latter type of modulation gives rise to stronger saliency effects and unbiased encoding of the center. Finally, we take an experimental perspective. Recently, both the presence and the underlying mechanisms of contextual modulations has been increasingly studied in mice using calcium imaging. However, cell signals extracted with calcium imaging are often highly contaminated by other sources. As contextual effects beyond center surround modulation can be subtle, a method is needed to remove the contamination. We present an analysis toolbox to de-contaminate calcium signals with blind source separation. This thesis thus expands our understanding of contextual modulation, predicts several new experimental results, and presents a toolbox to extract signals from calcium imaging data which should allow for more in depth studies of contextual modulation.