Estimating Nonlinear Receptive Fields from Natural Images

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Abstract

The response of visual cells is a *nonlinear* function of their stimuli. In addition, an increasing amount of evidence is showing that visual cells are optimized to process *natural images*. Hence, finding good nonlinear models to characterize visual cells using natural stimuli is important. The Volterra model is an appealing nonlinear model for visual cells. However, their large number of parameters, and the limited size of physiological recordings has hindered its application. Recently, a substantiated hypothesis that the responses of each visual cell could depend on a specially low-dimensional subspace of the image space has been proposed. We use this low-dimensional subspace in the *Volterra relevant-space technique* to allow the estimation of high-order Volterra models. Most laboratories characterize the response of visual cells as a nonlinear function on the low-dimensional subspace. They estimate this nonlinear function using histograms and fitting parametric functions to them. Here we compare the Volterra model with these histogram-based techniques. We use simulated data from cortical simple cells, and simulated and physiological data from cortical complex cells. Volterra models yields equal or superior predictive power in all conditions studied. Several methods have been proposed to estimate the low-dimensional subspace. In this paper we test Projection Pursuit Regression (PPR), a nonlinear-regression algorithm. We compare PPR with two popular models used in vision, spike-triggered average (STA) and spike-triggered covariance (STC). We observe that PPR has advantages over these alternative algorithms. Hence, we conclude that PPR is a viable algorithm to recover the relevant subspace from natural images and that the Volterra model, estimated through the *Volterra relevant-space technique*, is a compelling alternative to histogram-based techniques.

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