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  A geometric model of V1 neural selectivity

  We aim to predict physiological measurements of the neural responses of Macaque V1 cells to natural image stimuli. Standard reverse correlation techniques assume neurons to be linear in the pixel domain. However, a majority of V1 neurons are known to exhibit strong spatial non-linearities that cannot be characterized in this way (Theunissen et al, 2001). Here we propose a simple geometric model of V1 receptive fields that captures both linear and nonlinear properties in a unified way. The key hypothesis is that a V1 neuron is linear not over image pixels, but over the tangent bundle of the image patch within the cell's receptive field. We test this hypothesis against a database of V1 cell responses to natural image stimuli (Vinje and Gallant 2000). To estimate the model for each neuron, image patches are transformed into a sampled vector bundle representation, and neural responses are regressed against the vector coefficients. We demonstrate how the resulting geometric models capture properties of simple and complex cells in a unified way, and provide an intuitive method for expressing and visualizing both linear and nonlinear neural behaviour.

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