

# Energy Guided Diffusion for Generating Neurally Exciting Images

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## Abstract

In recent years, most exciting inputs (MEIs) synthesized from encoding models of neuronal activity have become an established method to study tuning properties of biological and artificial visual systems. However, as we move up the visual hierarchy, the complexity of neuronal computations increases. Consequently, it becomes more challenging to model neuronal activity, requiring more complex models. In this study, we introduce a new attention readout for a convolutional data-driven core for neurons in macaque V4 that outperforms the state-of-the-art task-driven ResNet model in predicting neuronal responses. However, as the predictive network becomes deeper and more complex, synthesizing MEIs via straightforward gradient ascent (GA) can struggle to produce qualitatively good results and overfit to idiosyncrasies of a more complex model, potentially decreasing the MEI's model-to-brain transferability. To solve this problem, we propose a diffusion-based method for generating MEIs via Energy Guidance (EGG). We show that for models of macaque V4, EGG generates single neuron MEIs that generalize better across architectures than the state-of-the-art GA while preserving the within-architectures activation and requiring 4.7x less compute time. Furthermore, EGG diffusion can be used to generate other neurally exciting images, like most exciting natural images that are on par with a selection of highly activating natural images, or image reconstructions that generalize better across architectures. Finally, EGG is simple to implement, requires no retraining of the diffusion model, and can easily be generalized to provide other characterizations of the visual system, such as invariances. Thus EGG provides a general and flexible framework to study coding properties of the visual system in the context of natural images.<sup>1</sup>

## 1 Introduction

From the early works of Hubel and Wiesel [1], visual neuroscience has used the preferred stimuli of visual neurons to gain insight into the information processing in the brain. In recent years, deep learning has made big strides in predicting neuronal responses [2–15] enabling *in silico* stimulus synthesis of non-parametric most exciting inputs (MEIs) [16–18]. MEIs are images that strongly drive a selected neuron and can thus provide insights into its tuning properties. Up until now, they

<sup>1</sup>The code is available at <https://github.com/sinxlab/energy-guided-diffusion>

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