Predictive Coding, Variational Autoencoders, and Biological Connections

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overview

Predictive Coding and **Variational Autoencoders (VAEs)** are highly related, providing a conceptual bridge between neuroscience and machine learning.

Neuroscience — **Machine Learning**

Predictive Coding // VAEs

Traversing this bridge implies surprising, new correspondences between these areas.

background

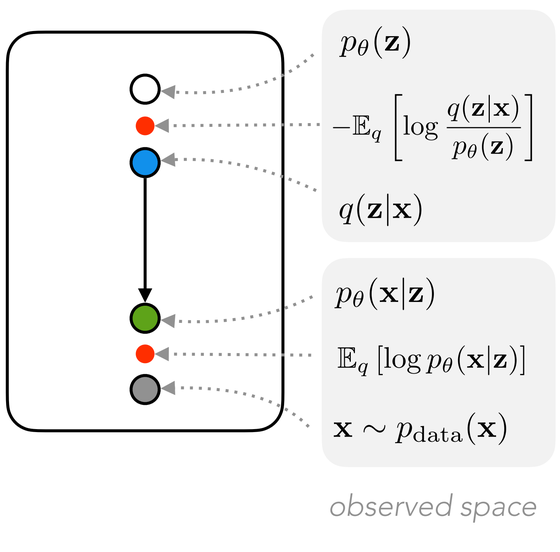
probabilistic models & inference

probabilistic model

$$p_\theta(\mathbf{x}, \mathbf{z}) = p_\theta(\mathbf{x}|\mathbf{z})p_\theta(\mathbf{z})$$

variational approx. posterior

$$q(\mathbf{z}|\mathbf{x})$$

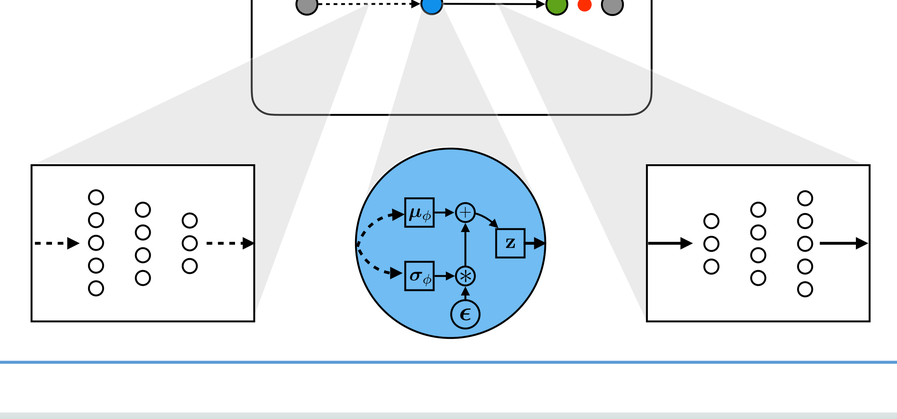


ELBO objective

$$\mathcal{L}(\mathbf{x}) = \mathbb{E}_q\left[\log p_\theta(\mathbf{x}|\mathbf{z}) - \log \frac{q(\mathbf{z}|\mathbf{x})}{p_\theta(\mathbf{z})}\right]$$

predictive coding

- model cortical hierarchy as a generative latent Gaussian model
- use prediction errors to update perceptual estimates (see below)

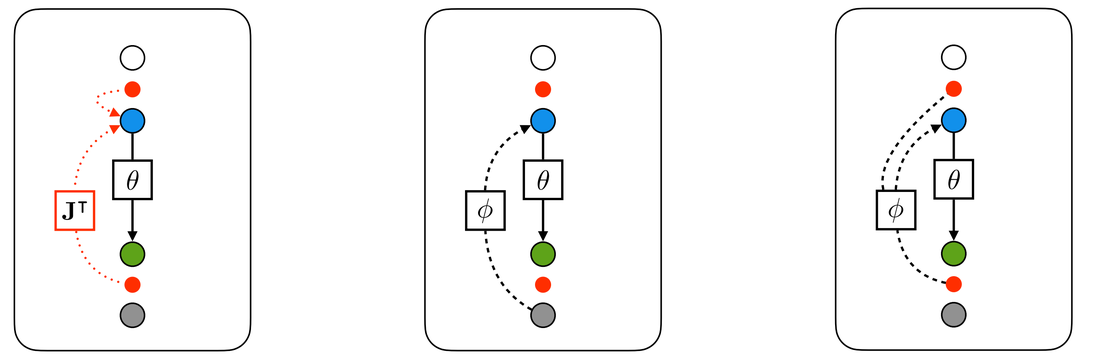


VAEs

- latent Gaussian model + deep networks
- *amortize* inference by use an encoder network

connections

predictive coding and **VAEs** both (typically) consider
- latent Gaussian models
- variational inference

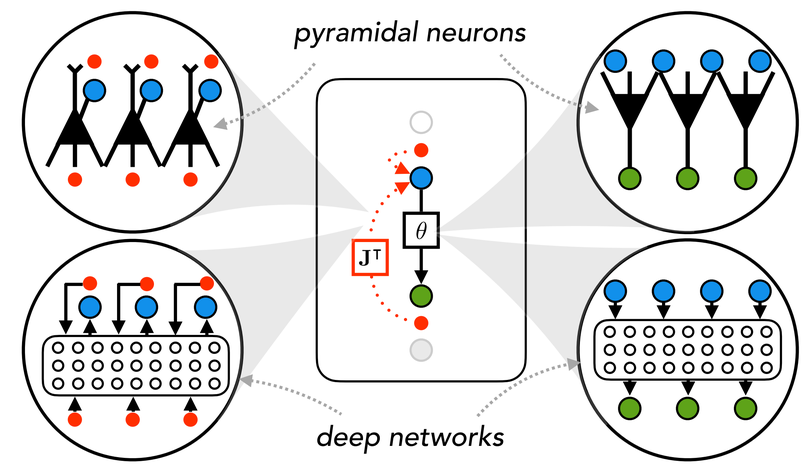


predictive coding — VAE (direct inference) — VAE (iterative inference)

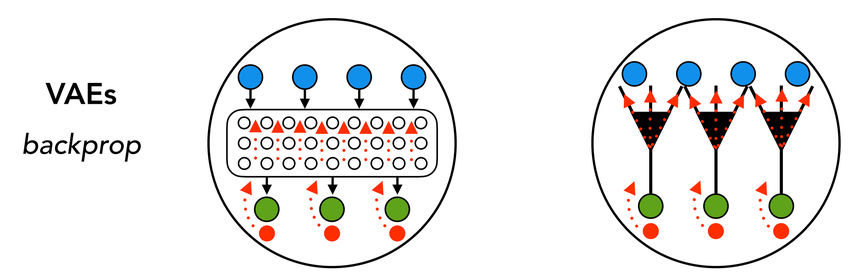
correspondences

pyramidal dendrites & deep networks

generative and inference conditional probabilities



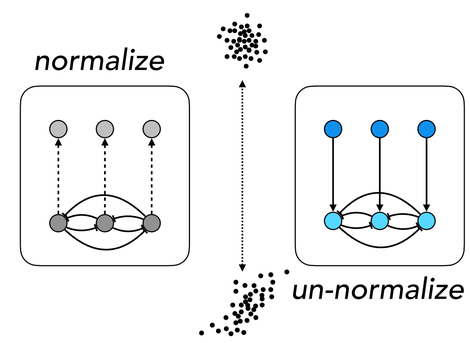
backpropagation *within* neurons

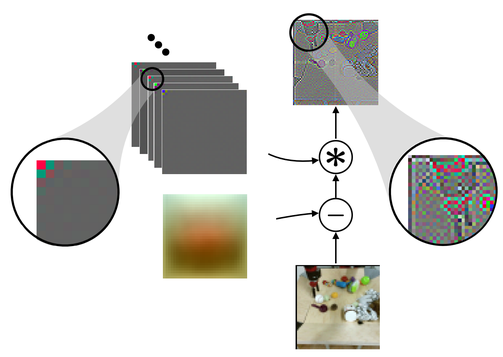


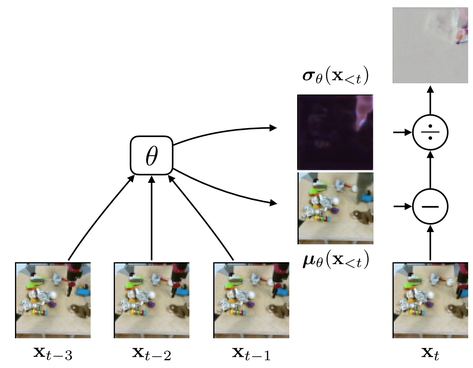
lateral inhibition & normalizing flows

add/remove dependencies using invertible local interactions

- *early sensory processing*
- *cortical lateral inhibition*
- *…*
- *central pattern generators*







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