Large-Scale Normative Theories, Probabilistic Models, and Brain Science

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Example:
Predictive Coding Model of the Visual Cortex
“Endstopping” in Cortical Neurons

Spikes fired by Neuron
Contextual Modulation in Visual Cortex

(Zipser et al., 1996)
Response of a retinal ganglion cell = difference (error) between center pixel values and their prediction based on surrounding pixels (Srinivasan et al., 1982)
Response of LGN cell = difference (error) between current pixel values and their prediction based on past pixel values

From: Dan et al., 1996
Predictive Coding Theory of Cortical Function

Predictive Coding Model:
Feedback = Prediction
Feedforward = Prediction Error

Inspired by Bayesian filtering algorithms

(Rao & Ballard, 1997, 1999; Rao, 1999)
Hierarchical Predictive Coding
Experiment:

fMRI Study

(Murray et al., 2002)
Other Examples

- Reinforcement Learning and Spike-Timing-Dependent Plasticity (w/ T. Sejnowski)
- Optimal Smoothing Theory, Postdiction, and Flash Lag Illusion (w/ D. Eagleman, T. Sejnowski)
- Partially Observable Markov Decision Processes and Decision Making in Primates (w/ M. Shadlen)
Conclusion: Major Themes

**Computer Science**
Models, Algorithms, Devices

- **Computational Level**
  Efficient coding, uncertainty, rewards/costs, optimization

- **Algorithmic Level**
  (Hierarchical) Bayesian inference & learning
  Acting under uncertainty via optimization of rewards

- **Computational Devices**
  Brain-Computer Interfaces (BCIs)
  Efficient algorithms for AI, ML, and Robotics
  Novel computer interfaces

**Brain Science**
Neural Solutions to Hard Problems

- **Implementation Level**
  Neural mechanisms of Perception, Action, Rewards, Behavior, Consciousness