

Introduction

- Predictive coding model of Rao and Ballard.
- Free-energy model of Friston.

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Summary of *A tutorial on the free-energy framework for modelling perception and learning* by Rafal Bogacz

└ Introduction

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1. Prior predictions are compared to stimuli and the model parameters are updated considering prediction errors, features corresponding to receptive fields in the the primary sensory cortex are learned.
2. Weight stimuli by their noise, learn features using their covariance, implement attentional modulation changing the variance of attended features.

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- Predictive coding model of Rao and Ballard.
- Free-energy model of Friston.
- Hebbian plasticity.

1. Prior predictions are compared to stimuli and the model parameters are updated considering prediction errors, features corresponding to receptive fields in the the primary sensory cortex are learned.
2. Weight stimuli by their noise, learn features using their covariance, implement attentional modulation changing the variance of attended features.
3. Synaptic strenght is changed proportionally to activities of pre-synaptic and post-synaptic neurons.

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- Predictive coding model of Rao and Ballard.
- Free-energy model of Friston.
- Hebbian plasticity.
- Free energy minimization.

- Predictive coding model of Rao and Ballard.
- Free-energy model of Friston.
- Hebbian plasticity.
- Free energy minimization.

1. Prior predictions are compared to stimuli and the model parameters are updated considering prediction errors, features corresponding to receptive fields in the the primary sensory cortex are learned.
2. Weight stimuli by their noise, learn features using their covariance, implement attentional modulation changing the variance of attended features.
3. Synaptic strenght is changed proportionally to activities of pre-synaptic and post-synaptic neurons.
4. Minimization of free energy can be seen as the base of many theories of perception.

- Local computation.

1. The state of a neuron is determined only by the synaptic weight and the state of its input neurons.

Working hypotheses

- Local computation.
- Local plasticity.

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- Working hypotheses

1. The state of a neuron is determined only by the synaptic weight and the state of its input neurons.
2. Synaptic plasticity depends only on the activities of pre-synaptic and post-synaptic neurons.

- Local computation.
- Local plasticity.

Working hypotheses

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- Working hypotheses

- Local computation.
- Local plasticity.
- Basic neuronal computation.

1. The state of a neuron is determined only by the synaptic weight and the state of its input neurons.
2. Synaptic plasticity depends only on the activities of pre-synaptic and post-synaptic neurons.
3. The state of a neuron is the result of the application of a monotonic function to the linear combination of states and synaptic weights of input neurons.

- Local computation.
- Local plasticity.
- Basic neuronal computation.

Single variable model

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- Single variable model

- └ Single variable model

- Feature is a scalar variable $v \in \Omega_v$.
- Stimulus is a scalar variable $u \in \Omega_u$.

1. The model describes the inference of a single variable from a single sensory input.

- Feature is a scalar variable $v \in \Omega_v$.
- Stimulus is a scalar variable $u \in \Omega_u$.

Single variable model

Exact solution to the inference problem

- Bayes theorem:

$$p(v|u) = \frac{p(v)p(u|v)}{p(u)} \quad . \quad (1)$$

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- └ Single variable model
 - └ Exact solution to the inference problem

1. Knowledge of feature depending on a given stimulus is the posterior. Prior knowledge on the feature is the prior, distribution of stimulus is the likelihood.

$$\hat{e}_u = \frac{u - g(v)}{\Sigma_u} \quad (5)$$



Fig. 3 from article: network implementation of the dynamical system

$$\begin{cases} \dot{\phi} = \varepsilon_u g'(\phi) - \varepsilon_p \\ \dot{\varepsilon}_p = \phi - v_p - \Sigma_p \varepsilon_p \\ \dot{\varepsilon}_u = u - g(\phi) - \Sigma_u \varepsilon_u \end{cases} \quad (6)$$

Neural implementation

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└ Single variable model

└ Neural implementation

- Note that all three hypotheses are satisfied.

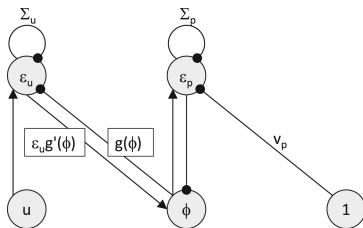


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$$\begin{cases} \dot{\phi} = \varepsilon_u g'(\phi) - \varepsilon_p \\ \dot{\varepsilon}_p = \phi - v_p - \Sigma_p \varepsilon_p \\ \dot{\varepsilon}_u = u - g(\phi) - \Sigma_u \varepsilon_u \end{cases} \quad (6)$$

Learning model parameters

- Choose model parameters to maximize $p(u)$.
- Equivalent to maximize negative free energy with respect to parameters:

$$\frac{\partial F}{\partial v_p} = \frac{\phi - v_p}{\Sigma_p} \quad , \quad (7)$$

$$\frac{\partial F}{\partial \Sigma_p} = \frac{1}{2} \left(\frac{(\phi - v_p)^2}{\Sigma_p^2} - \frac{1}{\Sigma_p} \right) \quad , \quad (8)$$

$$\frac{\partial F}{\partial \Sigma_u} = \frac{1}{2} \left(\frac{(u - g(\phi))^2}{\Sigma_u^2} - \frac{1}{\Sigma_u} \right) \quad . \quad (9)$$

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- Single variable model

- Learning model parameters

1. Model parameters are mean and variance of variables.
2. The fixed point of this dynamical system exists only as sample mean over the occurred events of perception.

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- Hebbian plasticity is satisfied using prediction errors.

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Single variable model

Learning model parameters

- Model parameters are mean and variance of variables.
- The fixed point of this dynamical system exists only as sample mean over the occurred events of perception.
- Without prediction errors, the computation is still local.

- Choose model parameters to maximize $p(u)$.
- Equivalent to maximize negative free energy with respect to parameters:

$$\frac{\partial F}{\partial v_p} = \frac{\phi - v_p}{\Sigma_p} \quad , \quad (7)$$

$$\frac{\partial F}{\partial \Sigma_p} = \frac{1}{2} \left(\frac{(\phi - v_p)^2}{\Sigma_p^2} - \frac{1}{\Sigma_p} \right) \quad , \quad (8)$$

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- Hebbian plasticity is satisfied using prediction errors.

Free energy framework

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- └ Single variable model
 - └ Free energy framework

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- └ Single variable model

- └ Free energy framework

Multiple variables model

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- └ Multiple variables model

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- └ Multiple variables model
 - └ Learning parameters

- Summary of *A tutorial on the free-energy framework for modelling perception and learning* by Rafal Bogacz
 - Multiple variables model
 - Learning parameters

Hierarchical structure implementation

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- Multiple variables model

└ Hierarchical structure implementation

Recover local plasticity

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- Multiple variables model

- └ Recover local plasticity

Conclusion

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Conclusion

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