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Complex synapses

A general theory of learning and memory with Complex
Synapses
based on work with Surya Ganguli

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April 8, 2013

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We often model synaptic plasticity as the change of a single number (synaptic weight). In reality, there is a complex dynamical system inside a synapse.

Semi-realistic models of synaptic memory have terrible storage without synaptic complexity.

We will study the entire space of a broad class of models of complex synapses to find upper bounds on their performance.

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Complex synapses

└ Introduction

1. amplitude of psp.
2. finite number of values.

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Semi-realistic models of synaptic memory have terrible storage without synaptic complexity.

We will study the entire space of a broad class of models of complex synapses to find upper bounds on their performance.

- 1 Why complex synapses?
- 2 Modelling synaptic complexity
- 3 Upper bounds
- 4 Envelope memory curve

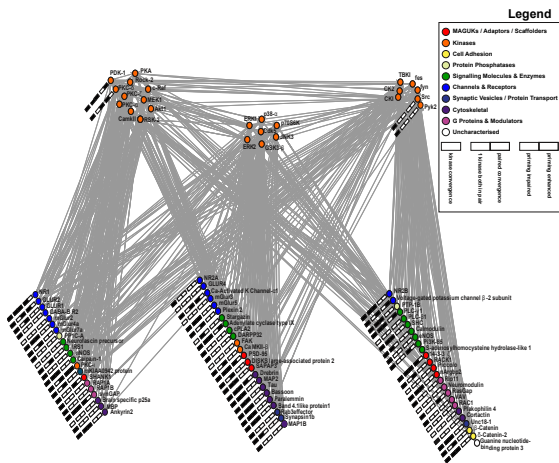
1. review terrible properties of simple synapses.
2. mathematical formalism of model, quantify performance (memory decay over time)
3. upper bounds on single numbers that describe performance at all times
4. upper bounds at finite times

Complex synapses
└ Why complex synapses?

Why complex synapses?

Why complex synapses?

Complex synapse



[Coba et al. (2009)]

There is a complex, dynamical molecular network underlying synaptic plasticity.

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Complex synapses
 Why complex synapses?
 Complex synapse

1. Does this matter?
2. Could just be the machinery for changing synaptic weight

Complex synapse



There is a complex, dynamical molecular network underlying synaptic plasticity.

[Coba et al. (2009)]

Storage capacity of synaptic memory

A classical perceptron (used as a recognition memory device) has a capacity $\propto N$, the number of synapses.

Requires synapses' dynamic range also $\propto N$.

If we restrict synaptic weight to a fixed, finite set of values,
 \implies tradeoff between learning and forgetting:
 new memories overwriting old.

If we wish to store new memories rapidly, memory capacity $\sim \mathcal{O}(\log N)$.
[Amit and Fusi (1992), Amit and Fusi (1994)]

To circumvent this tradeoff, need to go beyond model of a synapse as a single number.

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Complex synapses

- Why complex synapses?

- └ Storage capacity of synaptic memory

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Complex synapses
└─ Modelling synaptic complexity

Section 2

Modelling synaptic complexity

Section 2

Modelling synaptic complexity

- Complex synapses
 - Envelope memory curve

Envelope memory curve

Envelope memory curve

Thanks to:

- Surya Ganguli
- Stefano Fusi
- Marcus Benna

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Complex synapses

└ Envelope memory curve

└ Acknowledgements

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• Surya Ganguli
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1. Last slide!

References I



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