DISS. ETH NO. *(dissertation no.)*

BRAIN-INSPIRED MODELS AND SYSTEMS FOR DISTRIBUTED COMPUTATION

A thesis submitted to attain the degree of
DOCTOR OF SCIENCES of ETH Zurich

(Dr. sc. ETH Zurich)

presented by

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2017

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Lorem Ipsum

Chapter 1

Heading on level 0 (chapter)

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1.1 Heading on level 1 (section)

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1.1.1 Heading on level 2 (subsection)

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Heading on level 3 (subsubsection)

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Heading on level 4 (paragraph) Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Etiam lobortis facilisis sem. Nullam nec mi et neque pharetra sollicitudin. Praesent imperdiet mi nec ante. Donec ullamcorper, felis non sodales commodo, lectus velit ultrices augue, a dignissim nibh lectus placerat pede. Vivamus nunc nunc, molestie ut, ultricies vel, semper in, velit. Ut porttitor. Praesent in sapien. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Duis fringilla tristique neque. Sed interdum libero ut metus. Pellentesque placerat. Nam rutrum augue a leo. Morbi sed elit sit amet ante lobortis sollicitudin. Praesent blandit blandit mauris. Praesent lectus tellus, aliquet aliquam, luctus a, egestas a, turpis. Mauris lacinia lorem sit amet ipsum. Nunc quis urna dictum turpis accumsan semper.

1.2 Lists

1.2.1 Example for list (itemize)

- First itemtext
- Second itemtext
- Last itemtext
- First itemtext
- Second itemtext

Example for list (4*itemize)

- First itemtext
  - First itemtext
    - First itemtext
      - First itemtext
      - Second itemtext
    - Last itemtext
  - First itemtext
- Second itemtext

1.2.2 Example for list (enumerate)

1. First itemtext
2. Second itemtext
3. Last itemtext
4. First itemtext
5. Second itemtext

Example for list (4*enumerate)

1. First itemtext
   (a) First itemtext
      i. First itemtext
         A. First itemtext
         B. Second itemtext
      ii. Last itemtext
   (b) First itemtext
2. Second itemtext

1.2.3 Example for list (description)

First itemtext

Second itemtext

Last itemtext

First itemtext

Second itemtext

Example for list (4*description)

First itemtext

First itemtext

First itemtext

First itemtext

Second itemtext

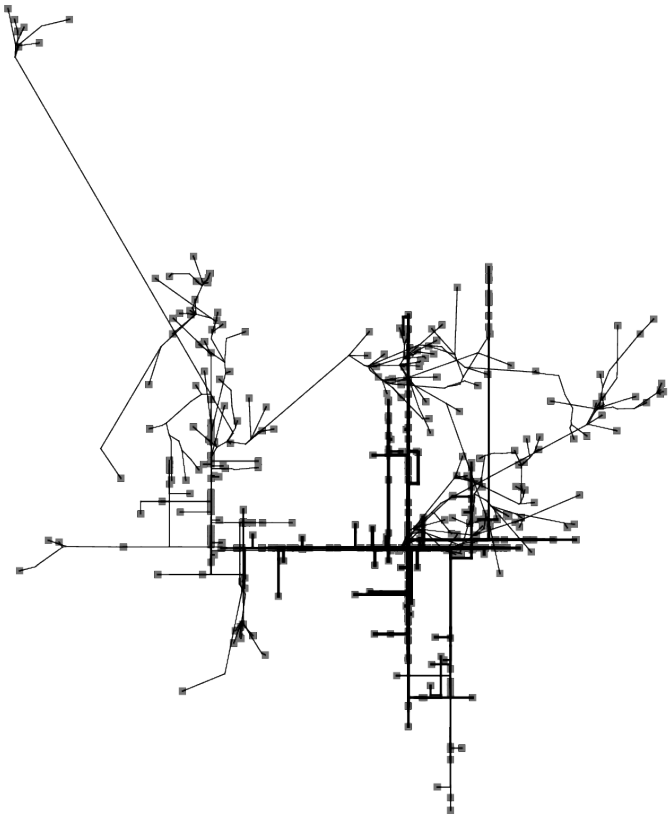
Last itemtext

First itemtext

Second itemtext

PART II

Computing with imprecise and noisy substrates



Introduction

Due to their organic nature, no two cells of a biological system, and therefore no two processing units of a brain, behave exactly the same. Signals are communicated electrically, chemically, on a molecular basis, and even mechanically, through the action of ion channels, whereby all of these processes are influenced by external factors, such as temperature, the abundance of various substances, and various sources of noise (Shadlen & Newsome, 1994).

Chapter 2

What is this all about?

Due to their organic nature, no two cells of a biological system, and therefore no two processing units of a brain, behave exactly the same. Signals are communicated electrically, chemically, on a molecular basis, and even mechanically, through the action of ion channels, whereby all of these processes are influenced by external factors, such as temperature, the abundance of various substances, and various sources of noise (Shadlen & Newsome, 1994).

2.1 Formal derivation

It is now easy to see that the state $\tilde{x}^{\mathsf{b}}$ corresponds to state x^{b} of the original model, since

$$\tilde{x}_k^{\mathsf{b}} = \sigma\left(\sum_{j<k} w_{kj} x_j^{\mathsf{f}} + \sum_{j>k} \tilde{w}_{kj}(x_j^{\mathsf{f}} + \Delta x_j) + b_k\right) \tag{2.1}$$

$$= \sigma\left(\sum_{j<k} w_{kj} x_j^{\mathsf{f}} + \sum_{j>k} \tilde{w}_{kj} x_j^{\mathsf{b}} + b_k\right) = x_k^{\mathsf{b}}\,. \tag{2.2}$$

Analogously to the original derivation, it can be shown that the first and the second forward passes, as well as the subsequent backward pass do not increase the system energy.

Bibliography

1. Shadlen, M. N. & Newsome, W. T. Noise, neural codes and cortical organization. *Current opinion in neurobiology* **4,** 569–579 (1994).