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OIST Computational Neuroscience Course (OCNC 2025) | Monday, June 23, 2025 (All day) to Thursday, July 10, 2025 (All day)

Computational Neuroscience Unit (Erik De Schutter)

FY2019 Annual Report

Computational Neuroscience Unit
Professor Erik De Schutter

See names on each tile, Dr. Sergio Verduzco is the unnamed person.

Abstract

We use computational, data-driven methods to study how neurons and microcircuits in the brain operate. We are interested in how fundamental properties, such as a neuron's morphology and its excitability, interact with one another during common neural functions like information processing or learning. Most of our models concern the cerebellum as this brain structure has a relatively simple anatomy and the physiology of its main neurons has been studied extensively, allowing for detailed modeling at many different levels of complexity.

1. Staff

- Molecular modeling
  - Iain Hepburn, Technical Staff
  - Andrew Gallimore, Researcher
  - Sarah Yukie Nagasawa, PhD Student
- Cellular modeling
  - Sungho Hong, Group Leader
  - Yunliang Zang, Researcher (till July 2019)
  - Aleksej Martynchev, Researcher
  - Gabriela Capo Rangel, Researcher (from November 2019)
  - Audrey Denizot, Researcher (from January 2020)
- Network modeling
  - Sergio Verduzco, Researcher
  - Peter Bratby, Researcher (till December 2019)
  - Mykola Medvidov, Staff Scientist
  - Mizuki Kato, PhD Student
- Software development
  - Weifeng Chen, Staff Scientist
  - Guido Klingbeil, Researcher (till June 2019)
  - Jules Lallouette, Researcher (from October 2019)
- Visiting Researcher
  - Jihwan Myung, Taipei Medical University
  - Samuel Melchior, EPFL
  - Tristan Carel, EPFL
  - Fernando Pereira, EPFL
  - Yoshiyuki Asai, Yamaguchi University Graduate School of Medicine
- Visiting Research Student
  - Taro Yasuhi (from December 2019)
- Research Interns
  - Pablo Santana Chacon (till June 2019)
  - Taro Yasuhi (June-December 2019)
  - Dorrell William Edward Charles (from February 2020)
- Rotation Students
  - Roman Koshkin(Term 1)
  - Duong Anh Tai Tran (Term 1)
  - Christin Puthur (Term 2)
  - Zhihguan Mu (Term 2)
- Research Unit Administrator
  - Chie Nanai

2. Collaborations

- **Theme: Cerebellar physiology, multiple themes**
  - Type of collaboration: Scientific collaboration and graduate program
  - Researchers:
    - Professor M. Giugliano, University of Antwerp, Belgium
    - Professor D. Snyders, University of Antwerp, Belgium
- **Theme: Spiking activity of monkey cerebellar neurons**
  - Type of collaboration: Scientific collaboration
  - Researchers:
    - Professor H.P. Thier, University of Tübingen, Germany
    - Akshay Markandey, University of Tübingen, Germany
    - Junya Inoue, University of Tübingen, Germany
    - Peter Dicke, University of Tübingen, Germany
- **Theme: Human Brain Project: simulator development**
  - Type of collaboration: Scientific collaboration
  - Researchers:
    - Prof. F. Schürmann, École Polytechnique Fédérale de Lausanne, Switzerland
    - Dr. S. Melchior, École Polytechnique Fédérale de Lausanne, Switzerland
    - Dr. T. Carel, École Polytechnique Fédérale de Lausanne, Switzerland
    - Dr. F. Pereira, École Polytechnique Fédérale de Lausanne, Switzerland
- **Theme: Molecular identification of cerebellar signaling pathways and cerebellar optogenetics**
  - Type of collaboration: Scientific collaboration
  - Researchers:
    - Professor K. Tanaka, Korea Institute for Science and Technology (KIST), Korea
- **Theme: Quantitative molecular identification of hippocampal synapses**
  - Type of collaboration: Scientific collaboration
  - Researchers:
    - Prof. Dr. Silvio O. Rizzoli, Medical University Göttingen, Germany
- **Theme: Cerebellar molecular layer interneurons**
  - Type of collaboration: Joint research
  - Researchers:
    - Professor Alain Marty, Université Paris 5 René Descartes, France
- **Theme: Cerebellar anatomy and physiology**
  - Type of collaboration: Scientific collaboration
  - Researchers:
    - Professor C. De Zeeuw, Erasmus Medical Center, Rotterdam, The Netherlands
    - Professor L.W.J. Bosman, Erasmus Medical Center, Rotterdam, The Netherlands
    - Dr. M. Negrello, Erasmus Medical Center, Rotterdam, The Netherlands
- **Theme: Purkinje cell morphology and physiology, modeling**
  - Type of collaboration: Scientific collaboration
  - Researchers:
    - Professor M. Häusser, University College London, United Kingdom
    - Professor A. Roth, University College London, United Kingdom
    - Dr. S. Dieudonné, École Normale Supérieure, Paris, France
- **Theme: Circadadian rhythm generation**
  - Type of collaboration: Scientific collaboration
  - Researchers:
    - Professor J. Myung, Taipei Medical University, Taiwan

3. Activities and Findings

FY2019 was a year with large personnel changes in the unit. As a consequence few papers were published though several manuscripts were submitted to journals.

3.1 Cellular mechanisms regulating firing and synaptic properties of neurons

Climbing fibers provide graded error signals in cerebellar learning

The cerebellum plays a critical role in coordinating and learning complex movements. Although its importance has been well recognized, the mechanisms of learning remain hotly debated. According to the classical cerebellar learning theory, depression of parallel fiber synapses instructed by error signals from climbing fibers, drives cerebellar learning. The uniqueness of long-term depression (LTD) in cerebellar learning has been challenged by evidence showing multi-site synaptic plasticity. In Purkinje cells, long-term potentiation (LTP) of parallel fiber synapses is now well established and it can be achieved with or without climbing fiber signals, making the role of climbing fiber input more puzzling. The central question is how individual Purkinje cells extract global errors based on climbing fiber input. Previous data seemed to demonstrate that climbing fibers are inefficient instructors, because they were thought to carry "binary" error signals to individual Purkinje cells, which constrains the efficiency of cerebellar learning in several regards. In recent years, new evidence has challenged the traditional view of "binary" climbing fiber responses, suggesting that climbing fibers can provide graded information to efficiently instruct individual Purkinje cells to learn. In Zang and De Schutter (2019) we review recent experimental and theoretical progress regarding modulated climbing fiber responses in Purkinje cells. Analog error signals are generated by the interaction of varying climbing fibers inputs with simultaneous other synaptic input and with firing states of targeted Purkinje cells (Figure 1). Accordingly, the calcium signals which trigger synaptic plasticity can be graded in both amplitude and spatial range to affect the learning rate and even learning direction.

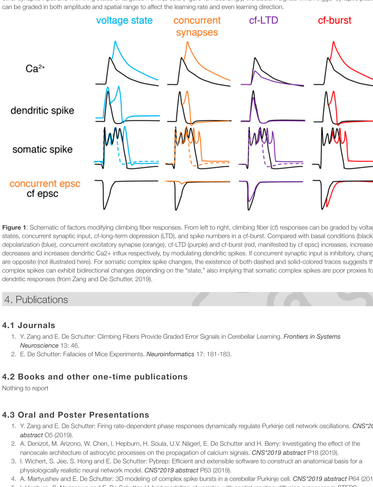

Figure 1: Schematic of factors modifying climbing fiber responses. From left to right, climbing fiber (cf) responses can be graded by voltage states, concurrent synaptic input, cf-long-term depression (LTD), and spike numbers in a cf-burst. Compared with basal conditions (black): depolarization (blue), concurrent excitatory synapse (orange), cf-LTD (purple) and cf-burst (red), manifested by cf epsc) increases, increases, decreases and increases dendritic Ca^{2+} influx respectively, by modulating dendritic spikes. If concurrent synaptic input is inhibitory, changes are opposite (not illustrated here). For somatic complex spike changes, the existence of both dashed and solid-colored traces suggests that complex spikes can exhibit bidirectional changes depending on the "state," also implying that somatic complex spikes are poor proxies for dendritic responses (from Zang and De Schutter, 2019).

4. Publications

4.1 Journals

1. Y. Zang and E. De Schutter: Climbing Fibers Provide Graded Error Signals in Cerebellar Learning. *Frontiers in Systems Neuroscience* 13: 46.
2. E. De Schutter: Fallacies of Mice Experiments. *Neuroinformatics* 17: 181-183.

4.2 Books and other one-time publications

Nothing to report

4.3 Oral and Poster Presentations

1. Y. Zang and E. De Schutter: Firing rate-dependent phase responses dynamically regulate Purkinje cell network oscillations. *CNS*2019 abstract* O5 (2019).
2. A. Denizot, M. Arizono, W. Chen, I. Hepburn, H. Soula, U.V. Nägerl, E. De Schutter and H. Berry: Investigating the effect of the nanoscale architecture of astrocytic processes on the propagation of calcium signals. *CNS*2019 abstract* P18 (2019).
3. I. Wichert, S. Jee, S. Hong and E. De Schutter: Pybrep: Efficient and extensible software to construct an anatomical basis for a physiologically realistic neural network model. *CNS*2019 abstract* P63 (2019).
4. A. Martynchev and E. De Schutter: 3D modeling of complex spike bursts in a cerebellar Purkinje cell. *CNS*2019 abstract* P64 (2019).
5. I. Hepburn, S. Nagasawa and E. De Schutter. Hybrid modelling of vesicles with spatial reaction-diffusion processes in STEPS. *CNS*2019 abstract* P65 (2019).
6. E. De Schutter and M. Kato: Agent based modeling of neural development with NeuroMaC. *Society for Neuroscience Abstracts*: 615.15 (2019).
7. A. Gallimore, "Alien Information Theory – Using the Neuroscience of Information to Understand the Reality-switching Effects of DMT" and "Towards a DMeTrix Machine – Developing DMT as a Technology for Communication with Interdimensional Alien Intelligences", Breaking Convention, UK, August 2019.
8. I Hepburn, AR Gallimore, SY Nagasawa, E De Schutter, Vesicle modelling extension to reaction-diffusion simulator STEPS, The 20th International Conference on Systems Biology, Okinawa, Japan, November 2019.
9. A. Martynchev and E. De Schutter: Modeling Purkinje neuron activity in 3D morphologies at the nanoscale, The 20th International Conference on Systems Biology, Okinawa, Japan, November 2019.
10. E. De Schutter, "Modeling synaptic plasticity: from physiology to cell biology", Invited lecture at Universitätsmedizin Göttingen, Germany, November 11 2019.
11. Denizot, "Astrocytes, the unacknowledged partners of neurons", Research Appreciation Week (RAW), My Research in 200s, OIST Japan, March 2nd 2020.

5. Intellectual Property Rights and Other Specific Achievements

Nothing to report

6. Meetings and Events

6.1 OIST Computational Neuroscience Course 2019

- Date: June 24 - July 11, 2019
- Venue: OIST Seaside House
- Organizers: Erik De Schutter (OIST), Kenji Doya (OIST), Bernd Kuhn (OIST), Tomoki Fukai(OIST) and Jeff Wickens (OIST)
- Speakers:
  - Erik De Schutter (OIST)
  - Kenji Doya (OIST)
  - Tomoki Fukai (OIST)
  - Wenbiao Gan (New York University, USA)
  - Geoff Goodhill (University of Queensland, Australia)
  - Jun Izawa (Tsukuba University, Japan)
  - Mike Hausser (University College London, UK)
  - Bernd Kuhn (OIST)
  - Suildin Lim (NYU Shanghai, China)
  - Eve Marder (Brandeis University, USA)
  - Greg Stephens (OIST)
  - Sebastian Seung (Princeton University, USA)
  - Taro Toyoizumi (RIKEN CBS, Japan)
  - Maryika Yoe Uusisaari (OIST)
  - Yi Zeng (Chinese Academy of Sciences, China)

6.2 Computational Neuroscience Unit Seminar

- Prof. Noam E. Ziv, "Synaptic tenacity or lack thereof: Spontaneous remodeling of synaptic connections", Rappaport Faculty of Medicine, and Network Biology Research Laboratories, Israel Institute of Technology, 24 April, 2019.
- Dr. Juyong Kang, "Energy landscape analyses of brain dynamics", Center for Systems and Translational Brain Sciences, Institute of Human Complexity and Systems Science, Yonsei University, South Korea, 23 December, 2020.

7. Other

Nothing to report.

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