Simulation of Astrocytic Calcium Dynamics in Lattice Light Sheet Microscopy Images

Anaïs Badoual, Misa Arizono, Audrey Denizot, Mathieu Ducros, Hugues Berry, U Valentin Nägerl, Charles Kervrann

To cite this version:
Anaïs Badoual, Misa Arizono, Audrey Denizot, Mathieu Ducros, Hugues Berry, et al.. Simulation of Astrocytic Calcium Dynamics in Lattice Light Sheet Microscopy Images. ISBI 2021 - IEEE International Symposium on Biomedical Imaging, Apr 2021, Nice, France. pp.1. hal-03516709

HAL Id: hal-03516709
https://inria.hal.science/hal-03516709
Submitted on 7 Jan 2022

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L’archive ouverte pluridisciplinaire HAL, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d’enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.
Simulation of Astrocytic Calcium Dynamics in Lattice Light Sheet Microscopy Images

A. Badoual1, M. Arizono2, A. Denizot3, M. Ducros4, H. Berry5,6, U.V. Nägerl7 and C. Kervrann5

1Inria, Centre de Recherche Bretagne Atlantique, Serpico Team, Rennes, France
2Interdisciplinary Institute for Neuroscience, UMR5297 CNRS, Bordeaux, France
3Computational Neuroscience Unit, Okinawa Institute of Science and Technology, Japan
4Inria, Centre de Recherche Rhône-Alpes, Boogie Team, F-69603, Villeurbanne, France
5Univ Lyon, LIRIS, UMR5205 CNRS, F-69621, Villeurbanne, France
6Univ Lyon, Inserm, UMR5297 CNRS, F-69621, Villeurbanne, France

ABSTRACT
Astrocytes regulate neuronal information processing through a variety of spatio-temporal calcium signals. Advances in calcium imaging started to reveal astrocytic activities, but the complexity of the recorded data strongly call for computational analysis tools. Their development is hindered by the lack of reliable annotations that are essential for their evaluation and for the design of learning-based methods. To overcome the labeling problem, we present a framework to simulate realistic astrocytic calcium signals in 3D+time lattice light sheet microscopy (LLSM) images by closely modeling calcium kinetics in real astrocytes.

RESULTS

• Simulation of Calcium Puffs
  - Kinetic model (nanoscale)
    $$ p(x) = \left\{ \begin{array}{ll} \gamma & \text{if } x \in A, \\ 0 & \text{otherwise}. \end{array} \right. $$
  - Temporal resolution
    $$ \Delta t = \frac{\Delta x}{v} $$
  - Indicator function of the subset
    $$ f(x) = \begin{cases} 1 & \text{if } x \in E, \\ 0 & \text{otherwise}, \end{cases} $$
  - Number of IP
    $$ N = \sum_{i=1}^{N} I_{A}(x_i) $$
  - Temporal resolution
    $$ \Delta t $$
  - Conductivity function
    $$ \beta = \left( \frac{v}{\Delta x} \right)^2 $$
  - Diffusion
    $$ \beta \Delta t = \left( \frac{v}{\Delta x} \right)^2 \Delta t $$
  - Maximum intensity
    $$ I_{max} = \left( \frac{v}{\Delta x} \right)^2 \Delta t $$
  - Stimulus
    $$ S(x) = \frac{1}{2\pi} \frac{1}{\Delta x} \sum_{i=1}^{N} \frac{I_{A}(x_i)}{I_{A}(x_i)} $$
  - Simulation of Calcium Puffs
    - Kinetic model (microscale)
      $$ f(x,t) = p(x) - \beta I(x,t) $$
    - Maximum intensity
      $$ I_{max} = \left( \frac{v}{\Delta x} \right)^2 \Delta t $$
    - Simulation of Calcium Waves
      $$ f(x,t) = p(x) - \beta I(x,t) $$

CONCLUSIONS
• Contributions
  - Generation of 3D-time LLSM images depicting astrocytic activity
  - Driven by a calcium kinetic model that we adapted from nanoscale to microscale
  - Image background made of realistic astrocytic ramifications
  - Simulation of experimental conditions of LLSM acquisitions (e.g., noise and blur)
  - Implementation as an ImageJ plugin with parameters and user interface
• Results
  - Variety of synthetic datasets that realistically represents the complexity of experimental data
  - Helpful to develop computerized learning-based methods to analyze astrocytic calcium signals in 3D+time images

REFERENCES