Spatial Coding in a Full-Scale Computational Model of the Hippocampus

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Information Coding in the Hippocampus

"WHAT"  "WHERE"

Context information  Spatial Information
perirhinal  postrhinal
LEC  MEC
CA1 distal  CA1 proximal
dentate gyrus
CA3

Place Cell on a Linear Track

Population of Place Cells on a Track

Knierim, 2012
Towards a Complete Description of the Circuitry Underlying Sharp Wave-Mediated Memory Replay

Colgin, 2017.

Nature Reviews | Neuroscience
Colgin, 2017.
1. **Computational level:** What is the task? What logic is used to solve it?

2. **Algorithmic level:** How is relevant information represented and manipulated to perform the task?

3. **Implementational level:** How does hardware implement the algorithms?

Understanding Neural Systems

Modeling hippocampal neuroanatomy and connectivity structure

Investigating hippocampal spatial and temporal coding at scale

Cell and circuit-level parameter optimization
Modeling the Hippocampus at Full Scale

Hippocampus of rat in 3D brain volume

3D distribution of 1,000,000 granule cells

Unique synthetic granule cell morphology

Axonal distributions
Modeling the Hippocampus at Full Scale

- 1.2M neurons
- 18B synapses

Dentate Gyrus Output to CA3

Hilus

Granule Cell Layer

Inner Molecular Layer

Middle Molecular Layer

Feedforward Input from MEC

Feedforward Input from LEC

Outer Molecular Layer

HICAP

HIPP

MC

BC

AAC

GC

MOPP

NGFC
Simulation of hippocampal spatial navigation

Example EC grid cell 2D spatial rate map

Location - X (cm)

Firing rate (Hz)

Input #

Time (ms)
Spatial coding of full-scale hippocampal simulation on Blue Waters

5 s physical time / 2048 BW nodes for 3 hrs
Nested parallel multi-objective optimization

https://github.com/neurosutras/nested
Realistic synaptic mechanisms compatible with full-scale simulations

Saturating AMPA-R + Facilitating NMDA-R

-- Blue Waters can simulate full-scale networks with unique synapses, but this is an inefficient use of resources
-- new synapse mechanism implementation combines biophysical realism with computational efficiency
Synaptic weight distributions

Buzsáki & Mizuseki
Nat. Rev. Neurosci., 2014
A scalable framework for parallel IO and analysis of full-scale neuronal network structure

Linden et al., Front Neuroinform. 2014

Connectivity
Morphology+
Biophysics
NeuroIO library
(C++ and Python)
PHDF5
MPI
NEURON Simulator (C++)
A scalable framework for generation, simulation, and analysis of full-scale neuronal network structure
Thank You!

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