CSE511 Brain & Memory Modeling

Lect01: Intro + Early BOSS Discrete Event Simulator

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http://www.cs.sunysb.edu/~cse511 and ~lw
CSE511 – Brain and Memory Modeling

Lecture Location: Room 2129 Computer Science Building
Time: 2:30PM - 3:50PM Tuesday/Thursday

Instructor: Prof. Larry Wittie
Office/Lab: CompSci Building, Room 1308
Office Hours: 3:55 - 5:25 PM Tu/Th or when door open
Phone in 1308: 631-632-8750
Email: lw AT icDOTsunysbDOTeduCourse
Homepage: http://www.cs.sunysb.edu/~511
CSE511 – Brain and Memory Modeling

CSE511 is a graduate-level course introducing neuroscience and brain structure modeling. There are no prerequisites except graduate standing in computer science or neurobiology (or instructor consent), but students are expected either to be capable of understanding and writing large modeling programs in either C, C++, or java or to have laboratory and literature experience with biological neuronal systems and to be willing to help others create realistic and useful neuronal modeling systems. This course will introduce computer brain modeling techniques:

1. Digital techniques for modeling the electrical activity in individual neurons and in collections of thousands, millions, and even billions of neurons.

2. Discrete event simulation methods in the BOSS system for modeling firing activity in ensembles of millions and billions of neurons.
CSE511 – Brain and Memory Modeling

CSE511 will also review the structure and function of human brain components, especially electrical signaling between neurons, the visual system, the cerebellum, the thalamus, the large cerebral neocortex, and synaptic plasticity => learning, memory, and recall.

1. The major structures of the human brain, its constituent glia and neurons, and the synapses connecting neurons.
2. How excited neurons generate electrical (ionic flow) firing spikes that influence electrical activity in other neurons.
3. Molecular changes in synapse membranes during learning and forgetting.
4. Neuronal interconnection structures to ensure stable levels of firing activity in massive collections of neurons.
5. The formation and re-creation of the stable, widely-distributed neuronal firing patterns hypothesized to be the basis for learning, memory, perception, and thought.
There will be one or two in-class quizzes on neuroscience material (from the text and lectures), an in-class midterm on brain and neuron functioning, plus a few small homework projects and one large final simulation and development project involving either the BOSS (C++) system (or frontend - INIT - or backend - visualizer - utilities for BOSS) or other programs for modeling neurons and brain structures.

The final grade will be based on: 10% Class participations, 10% quiz(es) 20% Homework exercises, 30% Midterm, and 30% Final project.

The workload is estimated to be about 5 hours per week, excluding the final project.

See website www.cs.sunysb.edu/~511 for possible projects for 2012.
Figure 1.2 Examples of the rich variety of nerve cell morphologies found in the human nervous system. Tracings are from actual nerve cells stained by impregnation with silver salts (the so-called Golgi technique, the method used in the classical studies of Golgi and Cajal). Asterisks indicate that the axon runs on much farther than shown. Note that some cells, like the retinal bipolar cell, have a very short axon, and that others, like the retinal amacrine cell, have no axon at all.

The drawings are not all at the same scale.
Figure 2 - Effects of synapse location on inputs as perceived at the soma. Inputs received at tips of dendrites are delayed and attenuated.
After input +ions raise axon transmembrane potential above threshold (-50 mv), a self-regenerating action potential ‘spike’ peak at +20 mv sweeps along the axon – at 0.5 meters/sec, in this image. The positive upward spike occurs as excess Na\(^+\) ions outside the axon rush in; it falls as inner K\(^+\) ions rush out 0.5 ms later. Proteins in axon walls restore the -65 mv resting potential by pumping Na\(^+\) ions outward and K\(^+\) ions inward for 2 ms after the spike.
Figure 1.9 Intracellularly recorded responses underlying myotatic reflex

Figure 1.9 Intracellularly recorded responses underlying the myotatic reflex. (A) Action potential measured in a sensory neuron. (B) Postsynaptic triggering potential recorded in an extensor motor neuron. (C) Postsynaptic triggering potential in an inhibitory interneuron. (D) Postsynaptic inhibitory potential in a flexor motor neuron.

Intracellular recordings like these are the basis for understanding the cellular mechanisms of action potential generation, and the sensory receptor and synaptic potentials that trigger these conducted signals.

NEUROSCIENCE, Fourth Edition, Figure 1.9
CSE511 Lect01-2: Intro+BOSS_DiscrEventSim
Discrete Event Simulator for Huge Networks

Steps to Simulate Networks of Many Millions of Neurons
1. Read BOSS parameters defining features of the network
   a) Physical dimensions of network
   b) Counts, placements, & thresholds of networked neuron types
   c) Counts, strengths, & relative places for inter-neuron synapses
   d) Runtime values, including start/stop times & forcing stimuli
2. (INIT) Fill data structure fields for each neuron soma (center)
3. (INIT) Find all axon-to-dendrite synapses between soma pairs
   a) If synapse patterns are irregular, this can be a slow \( O(N^2) \) step
   b) From parameters and locations, determine all fields for each synapse
   c) For fast runs, quantize all synapse delays into run-time-step units
4. (PreRun) Queue periodic stimuli to force neuron firing activity
5. (PreRun) Initialize starting activation levels of all neurons
6. Run BOSS discrete event simulator for each time step
   a) Execute each event pending for current time step
   b) Post each newly created event in pending event queue tails
   c) Check all neurons with activations increased in this time step
   d) Fire each neuron excited above its threshold and post new events for
each of its output synapses to other neurons.

BOSS V1-V6 2008-10 had regular overlapping axon fields
on a toroidal grid to simplify debugging of the C++ code.
BOSS V6 Fast Simulation: Threshold Element Grid

Output Fields of One Pair of Excitatory & Inhibitory Neurons

E #204 (+15) and I #205 (-1) Output (Axonal) Fields

This grid shows just 16 x 16 cells to fit on the slide. BOSS version-6 had 630 x 630 grids with 793,800 neurons and 101,606,400 synapses that filled the 1 GB of RAM on one NYBlue node.
Fast Simulation: 16x16 Grid of E, I Neuron Pairs

Outputs of Two Pairs of Excitatory and Inhibitory Neurons

Orange-Marked Inhibitory T-Elt #477 Uses End-Around Links

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E 476 (+15) and I 477 (-1) Fields
Fast Simulation: Neuron Cell & Link Arrays

Data Structures and Fields for Each Threshold-Element (Neuron Cell) and Its Output Links (Synapses)

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E 204 (+15) and I 205 (-1) Fields

I/E Inhibitory/Excitatory Index X,Y Location LkB,E: Links - Begin,End Indices

Cell X,Y Location LkB,E: Links - Begin,End Indices

Synapse Strength Linked Cell Index

8/28,30/2012 CSE511 Lect01-2: Intro+BOSS_DiscrEventSim
Fast Simulation: Centralized Event Queues

Pre-event delays quantized as cycles (time ticks) for speed. (Events posted for each cycle are not sorted more precisely.) (Max delay from current cycle for new event = MXCYC/2 -1.)

<table>
<thead>
<tr>
<th>Cycle</th>
<th>TimeUp[ ] Array of Event Queue Headers</th>
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Event example: start +15 pulse reaching cell 238 and post its -15 end-pulse event 2 cycles in future.

New event delays < MXCYC/2 means that event chains must be empty for cycles 488 thru 1000 (all except 1001 thru 1511 mod 1024) at the start of current cycle = 1001 if MXCYC = 1024.
Possible BOSS Projects

Samples of useful team (or individual or MS) BOSS projects

1. Extend 3D openGL visualizer utility by additional options
   a) Soma-to-synapse locations axon traces from selected neuron
   b) Soma-to-synapse locations axon traces to selected neuron
   c) All synapses-to-soma dendritic traces onto selected neuron
   d) Easier navigation thru and rotation of 3D image in view window
   e) Illustrate density of neuron firings by colors throughout image field

2. Make BOSS parameters easier to use and understand
   a) More meaningful names
   b) Floating point values, not integers over 1000 (T) or 1,000,000 (M)
   c) Clearer format for 2D SYNDIA entries giving synapse densities
   d) Alternatively, generate neuron classes from NeuroMorpho.org

3. Allow projection of periodic, external stimuli patterns onto neuron layers in a BOSS-created tissue model
Visualizer Image of a BOSS Cerebellar Model

Neuron Somas Within a Tiny Patch of Cerebellar Cortex from a Brain Tissue Model Set up by INIT

Neuron instances of eight model cell types: P Purkinje, N Granule, G Golgi, A|B right|left Basket, I|T|S Stellate cells. This visualizer snapshot shows 3D positions of neuron bodies in a cerebellar cortex model created by INIT. The granule cells (N) are irregularly placed; the Purkinje cells (P) are in staggered rows; and stellate (S,T,I) and basket (B,A) inhibitory neurons are placed regularly. Synaptic links are omitted.
Axonal (blue) and dendritic regions (green), where all synapses are located, are approximated as axis-aligned bounding boxes (AABBs). All instances of neurons of the same type have their field boxes in the same positions relative to the soma, or center of the cell. The two horizontal lines at the top of the image are the parallel fibers from the two granule cells. Each parallel fiber axon has a rising vertical segment before it bifurcates into horizontal segments that form hundreds of synapses with dendrites of Purkinje cells and of inhibitory interneurons up to 3 mm away longitudinally (Y) in both directions.
**Namelist Parameter Inputs To BOSS Version 8**

THESE ARE DEFINING PARAMETERS FOR CEREBELLAR MODEL

```
$PARAMS
MXCYCL = 15, MAXPVP = 1000,
NCELLT = 12, MCSPCY = 1000,
ABTHRS = 20,
MLONG = 1200, MTRAN = 1200,
$END
```

```
P N G B A S T I C M R D
P IS FOR PURKINJE CELLS
```

```
$CELL
MCL = 300, MCT = 300, MCTO = 150, MCVL1 = +00000,
MAL = 0002, MAT = 0002, MAV = 002, MALO = 0, MATO = +000, MAVO = -1000,
MDL = 30,2, MDT = 300,2, MDV = 300,2, MDV0 = 150,-5, DN = 2,
MMSDMN = 0200, MMSDMX = 0400, TDPFMN = 1000, TDPFMX = 1000,
TDLNRX = 1700, SMISNT = 1, OSNTYP = 0, MMSAS = 17000,
OSYNWT = 30, MCSODR = 10000,
XTHRES = 126, MCSPFR = 8000, GTHDKM = 800000,
SYNDA = 0000,0000,000,000,000,000,000,000,000,00000,1000,
$END
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...
**BOSS Input Parameters To Define Purkinje Cells**

MCL = 300, MCT = 300, MCTO = 150, MCVL1 = +00000, \{Neuron center spacing in microns\}
MDL = 30,2, MDT = 300,2, MDV = 300,2, MDV0 = 150,-5, DN = 2, \{Dendritic field sizes&offsets\}
MAL = 0002, MAT = 0002, MAV = 002, MALO = 0, MATO = +000, MAVO =-10000, \{Axon field\}
MMSDMN = 0200, MMSDMX = 0400, TDPFMN = 1000, TDPFMX = 1000,
SYNDA = 0000,0000,0000,0000,0000,0000,0000,0000,0000,0000,0000,1000, \{Dendritic neurons for P axons\}
TDLNRX = 1700, SMISNT = 1, OSNTYP = 0, MMSAS = 17000,
OSYNWT = 30, MCSODR = 10000,
XTHRES = 126, MCSPFR = 8000, GTHDKM = 800000,

P N G B A S T I C M R D
P IS FOR PURKINJE CELLS
N IS FOR GRANULE CELLS
G IS FOR GOLGI CELLS
B IS FOR BASKET CELLS WITH AXONS DIRECTED
  RIGHT (+T) OFFBEAM FROM SOMA
A IS FOR BASKET CELLS WITH AXONS DIRECTED
  LEFT (-T) OFFBEAM FROM SOMA
S IS FOR OUTER STELLATE CELLS (TYPE B) WITH
  AXON RIGHT (+T) OF SOMA
...
D IS FOR DENTATE AND OTHER SUBCORTICAL
NUCLEUS CELLS

8/28,30/2012 CSE511 Lect01-2: Intro+BOSS_DiscrEventSim
BOSS Input Parameters To Define Granule Cells

N IS FOR GRANULE CELLS

$CELL

MCL = 100, MCT = 100, MCTO = 000, MCVL1 = -50, MCV = -50, CVLN = 5,
TCVP = 200,200,200,200,200, TCVSF = 1000,1400,1750,2000,2250,
MMSDMN = 0400, MMSDMX = 0700, TDPFMN = 0990, TDPFMX = 1000,
TDLNRX = 6000, SMISNT = 0, OSNTYP = 1, MMSAS = 00300,
XTHRES = 40, MCSPFRR = 2000, GTHDKM = 700000,
SYNDA = 1000,000,250,750,750,750,750,750,750,0,0,0,0,0,
MALO = 0, MATO = +000, MAVO = +0300,
MAL = 2700, MAT = 0100, MAV = 100,
MDL = 50, MDT = 50, MDV = 50,
OSYNWT = 20, MCSODR = 50000,

$END

G IS FOR GOLGI CELLS ...

B IS FOR BASKET CELLS WITH ...

A IS FOR BASKET CELLS WITH ...

S IS FOR OUTER STELLATE CELLS ...

T IS FOR OUTER STELLATE CELLS ...

I IS FOR LOCAL INHIBITORY CELLS
(OUTER STELLATE, TYPE A) ...

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BOSS Input Parameters To Define Golgi Cells

G IS FOR GOLGI CELLS {PNGBASMARD}

$CELL {R IS FOR MOSSY FIBER ROSETTE TIPS, WITH AXONS COPIED BY GOLGI CELLS}

SYNDA = 0,0,0,0,0,0,0,0,-1000,0,
MCL = 600, MCT = 600, MCTO = 00,
MCVL1 = -00075,
MAL = 0600, MAT = 0600,
MAV = 250,
MALO = 0, MATO = +000,
MAVO = -0025,
MDL = 600, MDT = 600, MDV = 450,
MDVO = 000,
MMSDMN = 0450, MMSDMX = 1200,
TDPFMN = 0400, TDPFMX = 1000,
TDLNRX = 1000, SMISNT = 0,
OSNTYP = 0, MMSAS = 00600,
OSYNWT = -5, MCSODR = 50000,
XTHRES = 210, MCSPFR = 10000,
GTHDKM = 766700,

$END
BOSS Parameters To Define Mossy Axon Rosettes

R IS FOR ROSETTE TIPS (AXONS COPIED BY GOLGI-S)  \{P N G B A S T I C M R D\}

$CELL$
SYNDA = 0.962,1000,0,0,0,0,0,0,0,0,0,0,
0,0,0,
MCL = 160, MCT = 160,
MCVL1 = -90,
MCV = -120, CVLN = 2,
TCVP = 500,500,
MAL = 400,
MAT = 400, MAV = 130,
MDL = 160, MDT = 160,
MDV = 2,
MMSAS = 500,
MMSDMIN = 1000,
MMSDMX = 1000,
OSYNWT = 20,
MCSODR = 50000,
TISDRF = 1,
XTHRES = 1,
GTHDKM = 1000000,

$END$
BOSS Projected Stimuli to Image Processing Array

\$FORCE\nFORCEZ = 10, \{'0' => -10, '9' => -1, 'A' => 0, 'B' => 1\} FROM = 0, TO = 1000, ON = 250, OFF = 0, \$END

Greyscale image to excite/inhibit sensors

Darkened points, excited +20 to 225

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BOSS Parameters for IC Image Processing Array - 1

$PARAMS
MLONG = 350, MTRAN = 1230, NCELLT = 5, MCSPCY = 100000,
ABTHRS = 0, NXCPTN = 2, PRTMOD = 10,
$END

I S + . X

I FOR INPUT ELEMENT (DISPLAYS LOG OF EXCITATION)
$CELL
FCH = 14, MCLMN = 11, MCLMX = 340, MCTMN = 31, MCTMX = 300, MCL = 10,
MCT = 10, MMSAS = 1000, MATO = 600, DN = 0, SYND = 0,0,0,1000,0, {I => .}
$END

S FOR SUM ELEMENT (DISPLAYS EXCITATION) (USED TO COUNT OUTPUTS)
$CELL
FCH = 24, XTHRES = 0, MCLMN = 61, MCLMX = 290, MCTMN = 941,
MCTMX = 1200, MCL = 110, MCT = 30, AN = 0, MDL = 110, MDT = 30,
MMSDMN = 1000, MMSDMX = 1000, SYND = 0,0,0,0,0, {no axonal outputs}
+ FOR OR GATE
$CELL
FCH = 34, MCLMN = 11, MCLMX = 340, MCTMN = 331, MCTMX = 600,
MCL = 10, MCT = 10, MMSAS = 1000, MMSDMN = 1000, MMSDMX = 1000,
MATO = 300, SYND = 0,0,0,1000,0,
{+ => .}
$END

Greyscale image to excite sensors

Dark and X-connected points

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BOSS Parameters for IC Image Processing Array - 2

. FOR AND GATE     (& OUTPUT ELEMENT)
$CELL
FCH = 61, XTHRES = 2, MCLMN = 11, MCLMX = 340, MCTMN = 631, MCTMX = 900,
MCL = 10, MCT = 10, MMSAS = 1000,1000,1000,1000,1000, AN = 5,
MMSDMN = 1000, MMSDMX = 1000, MMSDMN = 1000, MMSDMX = 1000,
MALO = 0,0,10,0,-10, MATO = 300,-290,-300,-310,-300, SYNDX = 0,1000,1000,0,0, {. => S, +}
$END

X IS CENTER NEURON REDUCING THRES OF CENTRAL AND-GATE TO 1 INSTEAD OF 2
$CELL
FCH = 29, XTHRES = 0, MCLMN = 3, MCLMX = 3, MCTMN = 761, MCTMX = 761,
MCL = 2, MCT = 2, MMSAS = 1000, DN = 0, MALO = 168, SYNDX = 0,0,0,1000,0, {X => .}
$END

T => 31 – 300  331 – 600  631 – 900  941 – 1200
    761
3   11    I I I I I I     + + + + + +    . . . . . .
L  61    I I I I I I     + + + + + +    . . . . . .    S S S S S S S
61    I I I I I I     + + + + + +    . . . . . .    S S S S S S S
  I I I I I I     + + + + + +    . . . . . .    S S S S S S S
290   I I I I I I     + + + + + +    . . . . . .    S S S S S S S
V  340   I I I I I I     + + + + + +    . . . . . .    S S S S S S S

Layout of IC gates in L x T plane    For BOSS inputs, see files:
Boss23-36AllDataSrcsWithoutMapCdsFIXED.rtf & AllNamelist+Other_Input_BOSScode.rtf &
BossOrigFixed0303mitLNo.doc & Boss1-185ALLsrcTypeModLineCol72SrdtRefFA1013.xls
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BOSS Projected Stimuli to Image Processing Array

Greyscale image to excite/inhibit sensors

Darkened points, excited +2^0 to 2^25

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Output from BOSS Simulated Image Processor

Greyscale Image to Process  + OR on => connected pt  Dark & X-connected pts

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Major BOSS \$CELL \{& \$GNCELL\} Namelist Parameters

All \$CELL \$END parameters are arrays. Most have one entry for each of the NCELLT cell types. A few, including, MALO,MATO,MAVO,MAL,MAT,MAV,TAD,MMSAS,MDLO,MDTO, MDVO,MDL,MDT,MDV,TDD,OSYNWT, are 2 dimensional. These few depend either on the number of axonal (output) AN or dendritic (input) DN potential connection regions per neuron (cell) of this type. A very few, namely, TCVP and TCVSF, also depend on the number of vertical levels of neuron centers as well as cell type.

One, SYND, is two-dimensional in the number of cell types. It lists dendrite(NCELLT) x axon(NCELLT) synapse (connection) densities in regions wherever a dendritic (input) region of one cell overlaps an axonal (output) region of another cell.

In the \$CELL \$END array dimension declarations, MXCELT is the maximum number of cell types, including one dummy type created by BOSS to lessen edge effects that otherwise give lower activity levels for cells near simulation boundaries. (The dummy cells collect axonal outputs that cross the simulation boundaries and periodically issue a corresponding number of outputs to dendritic inputs for cells near a simulation boundary.)

MXCELM is the maximum value of NCELLT, the number of cell types that a user may specify; it is one less than MXCELT. The following array declarations give the maximum number of entries for one \$CELL parameter {or one \$GNCELL (generated from \$CELL) parameter}.

{The \$GNCELL namelist is very short. Its five entries are all arrays with one or more entries for each of the NCELLT cell types. (Each array is one- or two-dimensional.) These array values are never input directly; rather, the value of each entry is calculated after all \$CELL \$END inputs have been read. The \$GNCELL declarations are marked with blue (PROGram GENerated) notes. (\$GNCELL declarations are not shown in these slides.)}

For the first version of BOSS, MXCELM=19, MXCELT=20, MXNFLD=8, and MXNLVL=10.
The $PARAMS, $CELL & $GNCELL Namelist Parameters

From lines IGNI 000184-000189 and 000367- 00392:
NAMELIST /PARAMS/ ABTHRS, CYDBG2, CYDBG3, CYDBG4, EXCITE, MAXERR, MAXPVP, MAXSYP, MAXVMP, MCSPCY, MINFIR, MLONG, MTRAN, MXCYCL, MXNOFR, NCELLT, NLOGXN, NREGXN, NXCPTN, PRTMOD, TOFLFP, TSNMNP, TXMDES, TXMDIS

$PARAMS default values:
ABTHRS_AbsoluteFiringThresholdForAllCells = 1,
CYDBG2_CycleToBeginUsingNextSetOfDebugFlags = CYDBG3 = CYDBG4 = 654321, {=> never}
EXCITE_ForcedExcitationForAllCellsOnCycle0IfNonZero = 0,
MAXERR_MaxNumberOfSystemErrorsBeforeKillJobObsolete = 1,
MAXPVP = 2000,
MAXSYP = 2000,
MAXVMP = 4000,
MCSPCY_MicroSecondsPerCycle = 250, {short step OK for most neurons}
MINFIR_ = 2,
MLONG = 2400,
MTRAN = 4500,
MXCYCL = 0,
MXNOFR_MaxNumberOfCyclesWithoutAnyFiringBeforeHaltSimulation = 10,
NCELLT_NumberOfDefinedCellTypes = 0, {must input to run}
NLOGXN = 1,
NREGXN = 2,
NXCPTN = 0,
PRTMOD[1] = 1, PRTMOD[2,3,4] = 0,0,0
TOFLFP = 1000,
TSNMNP = 1000,
TXMDES = 1000,
TXMDIS = 1000,

Notes taken from comments in AllNamelist+Other_Input_BOSScode.rtf
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Slow Simulation: Small Edge vs Center Ratio

Grid 32x32 too small for 4 regions with core+edge queues

Core Work Cannot Hide Edge Exchanges (each edge 5 wide).

Core Boxes 6x6 = 36 locs
Edge Rings 16x16-36 = 220 locs
Grain Size $\approx \frac{36}{220-36} = 0.2$
(0.2 is bad since < 1)

Exchange Most Results.
Edge Queues Do 6X Work of Cores
Faster Simulation: Larger Edge/Center Ratio

Grid 64x64 good for 4 regions with core+edge queues
Core Work Will Hide Edge Exchanges.

Core Boxes 22x22 = 484
Edge Rings 32x32-484 = 540
Grain Size ≈ 484/(540-484) ≈ 8.6 >> 1
(Grain Size = CompTime/ExposedCommTime)

Exchange ~1/2 of Results.
Edge Queues Do 1.1X Work of Cores
Use Four Pairs of Event Queues.

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Overview: Brain Organization Simulation System (BOSS)

A Billion Pencils For Neuroscience Modeling

Given statistical descriptions of the classes of constituent neurons and of the synapses between pairs of neurons, BOSS computer software automatically generates brain tissue models containing many thousands (or millions) of realistically placed electrically active elements (neurons) and millions (or billions) of properly configured one-way electrical connections (axon to dendrite synapses) between pairs of neurons. The statistical descriptions for each constituent class of neurons in the tissue specify the spacing of neuron center (soma) positions, the locations relative to each center of that neuron's input (dendritic) and output (axonal) regions, and the density and the signal passing characteristics of its synapses with other neurons of each class, including its own.
BOSS allows quick, but detailed prediction and recording of the rapid ionic flow (spike firing) interactions of individual neurons and their tissue-wide electrical activity patterns, even for tissue models containing many thousands of neurons and millions of synapses between neurons. A neuroscience researcher can easily create tissue models containing huge numbers of neurons by specifying only a few dozen to a few hundred parameters. Model initialization ("front-end") routines use the parameters to create the millions or billions of specific details that precisely describe a representative model of the tissue. Model simulations are efficient because, as much as allowed by the underlying ("back-end") simulation engine, all model details of signal characteristics and of three-dimensional distances between neurons and synapses are reduced to precise numeric values of ionic signal strengths and of time delays that require very few or no additional transformations during model execution.
The BOSS discrete-event simulator back-end for BOSS

The first implementation of BOSS is designed to target a rapidly executing quantitized-time discrete-event simulator, BOSS. However, BOSS should be fairly easy to extend to target other back-end neuronal simulation systems, such as NEURON from Yale.

The BOSS simulator avoids computationally expensive sorting of future event lists by time-of-occurrence. Instead of searching lengthy lists of future events whenever a new event is posted for later execution, BOSS provides a separate, never-sorted queue of events for each future time quantum ("clock tick") at which any event can occur if it is created during the current simulation clock tick.
A circular header array ("UpTime") of event queue head and tail pointers allows the right position for a new event to be determined immediately without sorting, simply by adding - modulo UpTime_size - the current time tick to the quantized delay time for the new event. Each new event is appended to the tail of the event queue for its time tick and the tail pointer is updated to point to it.

When BOSS finishes performing the specified actions for all events posted to occur during the current time tick, it adds 1, modulo UpTime_size, to the current tick counter to index the UpTime head and tail pointers for all events that will happen during the next simulation time tick. The first event is indicated by the head pointer in the new UpTime header. As each event specifier is removed from the current event queue, the head pointer in UpTime is updated to the next event in the queue.
UpTime contains as many entries for event queue headers as twice the number of ticks for the longest pre-occurrence delay for any event that can be created in the brain tissue model that has just been created by BOSS. By setting the time quantum (tick) smaller, a researcher can get more precise predictions of brain tissue electrical activity. By setting the tick larger, a researcher can reduce BOSS execution wall-clock times.

Since a neuron cannot normally initiate more than one firing spike per millisecond (ms) and usually fires much less rapidly, BOSS simulations do not normally benefit from time ticks shorter than 0.1 ms. Even 10.0 ms ticks give fast but acceptable results for most models, at least during initial model validation and refinement runs. If nervous system signal propagation delays rarely exceed 50 ms, even with time ticks set at a rapid 0.1 ms, UpTime is small in size, needing at most 1,024 queue header entries. For 1 ms time steps, only 16 to 24 headers are needed for most models that we have run.