Visualizing Network Connectivity with ConnPlotter

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Simula Research Laboratory
RIKEN Brain Sciences Institute

8 October 2009

Party!

Network Diagrams

Connectivity Pattern Tables

ConnPlotter

Perspectives

Outline

Happy Birthday, Neural Network Simulators!

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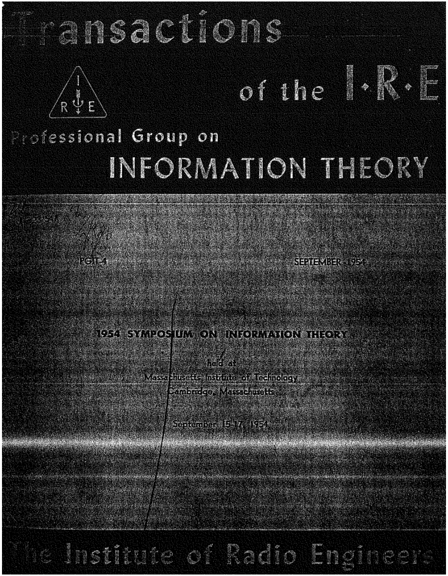
Perspectives

Happy Birthday, Neural Network Simulators!

Network Simulation: 55 years!



Transactions of the I·R·E

Professional Group on
INFORMATION THEORY

PGIT-4 SEPTEMBER 1954

1954 SYMPOSIUM ON INFORMATION THEORY

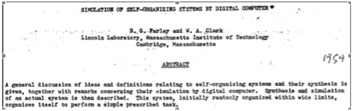
held at
Massachusetts Institute of Technology
Cambridge, Massachusetts

September 15-17, 1954

The Institute of Radio Engineers

B. G. Farley & A. W. Clark, 1954

- *Simulation of self-organized systems by digital computer*
- MIT Memory test computer
  - 4096 16-bit words
  - 90.000 fetch/add per sec
- 64 leaky I&F neurons
- δ-synapses w/ delay
- exponentially decaying threshold
- Gaussian noise (LFG)
- 75% connectivity
- Hebbian learning



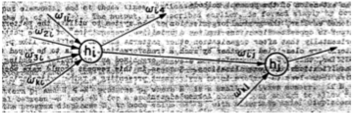
SIMULATION OF SELF-ORGANIZING SYSTEMS BY DIGITAL COMPUTER*

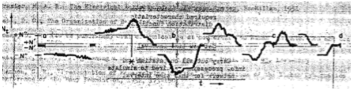
B. G. Farley and W. A. Clark
Lincoln Laboratory, Massachusetts Institute of Technology
Cambridge, Massachusetts

1954

ABSTRACT

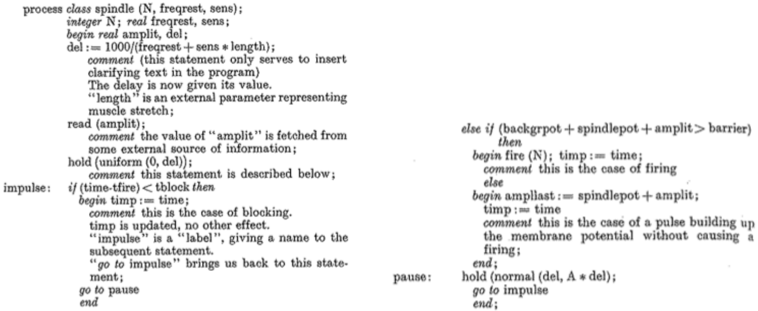
A general discussion of ideas and definitions relating to self-organizing systems and their synthesis is given, together with remarks concerning their simulation by digital computer. Synthesis and simulation of an actual system is then described. This system, initially randomly organized within wide limits, organizes itself to perform a simple prescribed task.





First Neuron Class: 40 years!

- Lars Walløe, J. K. S. Jansen, Kirsten Nygaard
- *A Computer Simulated Model of a Secondary Order Sensory Neuron*
- Kybernetik **6**:130–141 (1969)
- Model of neurons in dorsal spino-cerebellar tract
- Direct comparison to experimental data
- Implemented in Simula on a Univac 1107



```
process class spindle (N, freqrest, sens);
         integer N; real freqrest, sens;
         begin real amplit, del;
         del := 1000/(freqrest + sens * length);
              comment (this statement only serves to insert
              clarifying text in the program)
              The delay is now given its value.
              "length" is an external parameter representing
              muscle stretch;
         read (amplit);
              comment the value of "amplit" is fetched from
              some external source of information;
         hold (uniform (0, del));
              comment this statement is described below;
impulse: if (time-tfire) < tblock then
           begin timp := time;
              comment this is the case of blocking.
              timp is updated, no other effect.
              "impulse" is a "label", giving a name to the
              subsequent statement.
              "go to impulse" brings us back to this state-
              ment;
           go to pause
           end

         else if (backgrpot + spindlepot + amplit > barrier)
              then
           begin fire (N); timp := time;
              comment this is the case of firing
              else
           begin ampllast := spindlepot + amplit;
              timp := time
              comment this is the case of a pulse building up
              the membrane potential without causing a
              firing;
           end;
pause:   hold (normal (del, A * del));
           go to impulse
           end;
```

Network Diagrams

What makes science science?

Refutable hypotheses

Hypotheses must be stated with sufficient detail and precision so that one can devise meaningful tests or counterexamples.

Reproducible experiments

Experiments must be described and performed so carefully, that others can *reproduce* them. Genuine failure to reproduce results invalidates original findings.

Accumulation of knowledge

Accumulation of knowledge through exchange, evolution and (sometimes) revolution of ideas.

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What do we need?

- Reliable,
- Precise,
- Expressive,
- Easy-to-Use
- means to visualize our models of neuronal networks.

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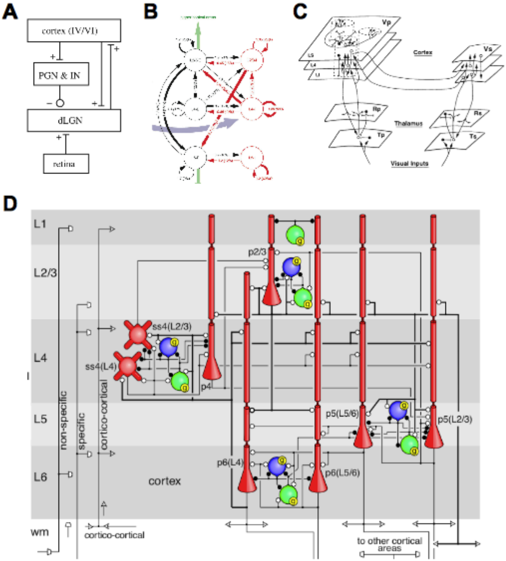
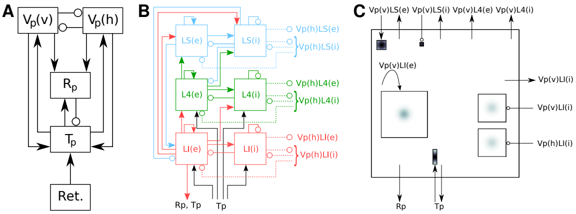
What do we have?

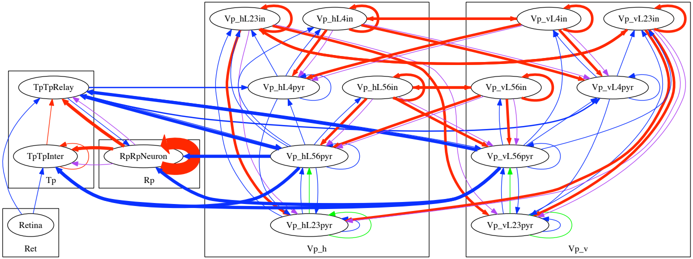


What can we do?

- Develop standards for symbols (eg Kitano et al, Nature Biotechnol 2005)
- Draw network at different levels (from Nordlie et al, 2009)
- 

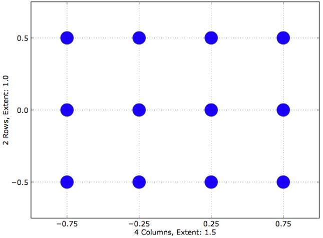
- Problems:
  - How to generate automagically?
  - Confusing line crossings

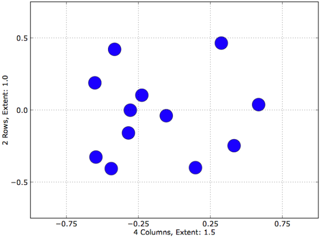
Dot doesn’t help . . .



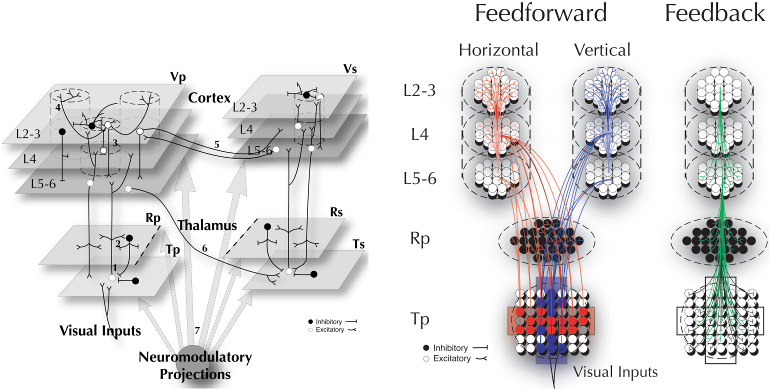
Connectivity Pattern Tables

NEST Topology: Simple Layers



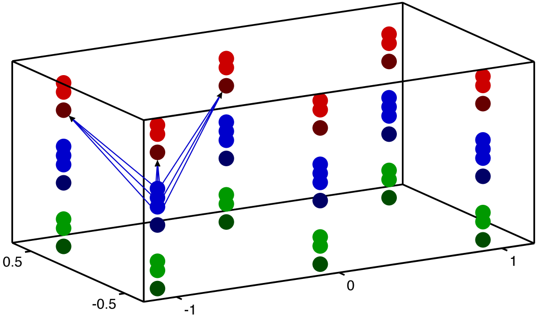


Real networks: Complex Layers



From Hill & Tononi, J Neurophysiol, 2005, 93, 1671–1698

NEST Topology: Composite Layer Elements



- Each color represents a neuron model
- Connections are made by specifiying entire layer and model to connect to/from

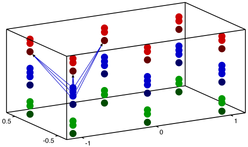
Populations, Groups, Projections

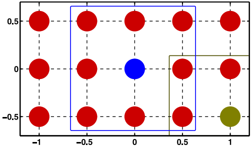
Population Homogeneous group of neurons with 2D-layout

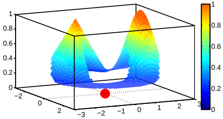
Group Collection of populations, e.g., a layer

Projection Rule for connecting two populations

- **Mask** Only target population neurons inside mask are connected
- **Kernel** Probability of connection
- **Synapse model**

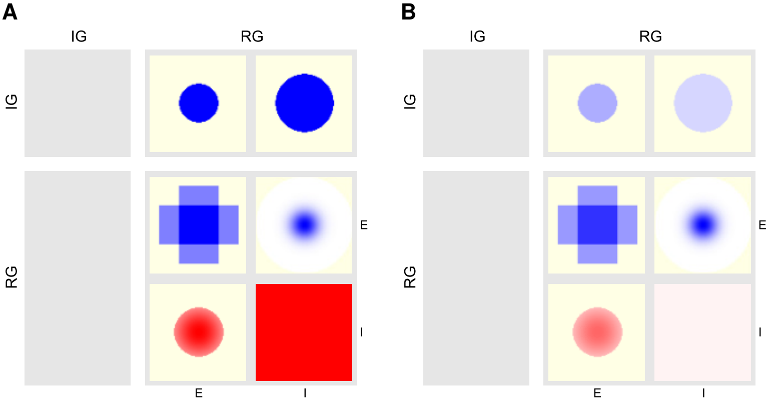






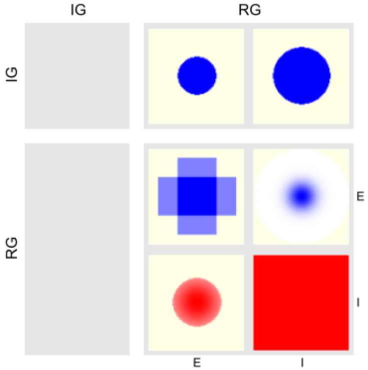
Connectivity Pattern Table (CPT)

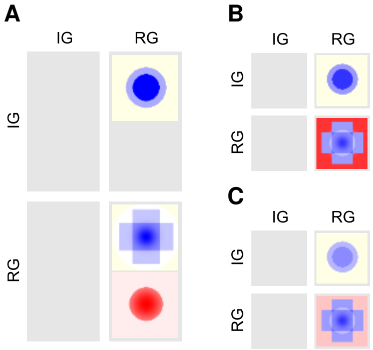
- Connectivity matrix showing kernels & masks
- Intensity = weight × probability



Aggregate CPTs

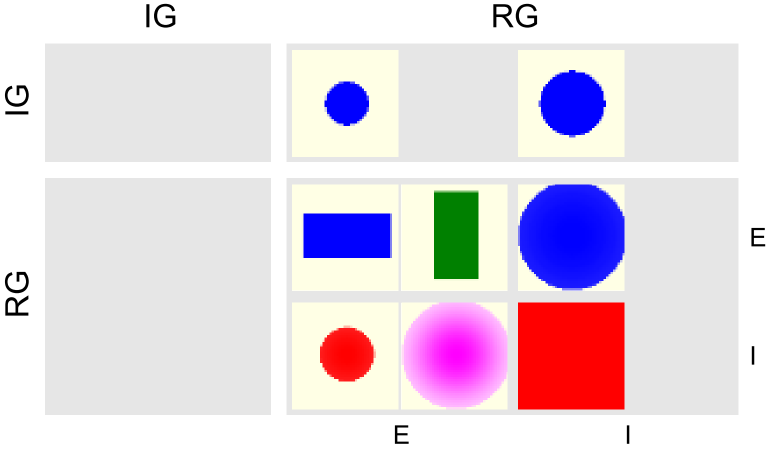
- Condense by combining across populations, synapse models, or both



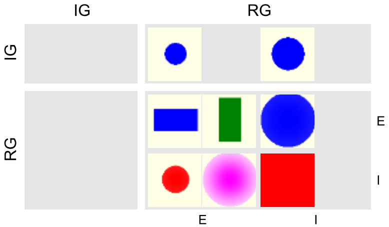


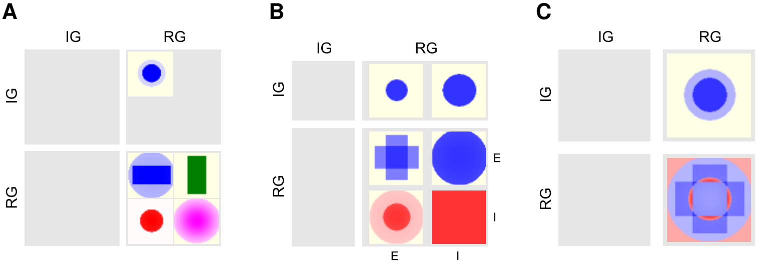
Different synapse types

- Different colors
- Co-occurring types placed side-by-side

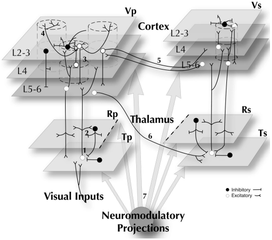


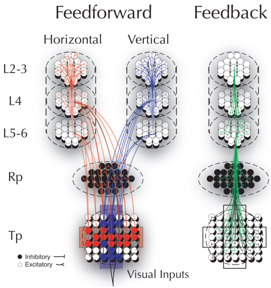
Aggregate with synapse types

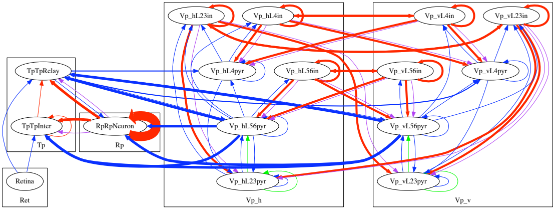




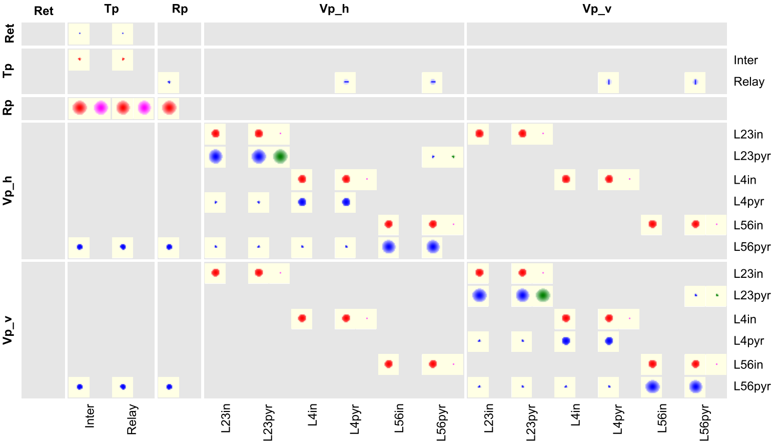
The Hill-Tononi Model . . .







. . . and as CPT


Ret
Tp
Rp
Vp_h
Vp_v
Ret
Tp
Rp
Vp_h
Vp_v
Inter
Relay
L23in
L23pyr
L4in
L4pyr
L56in
L56pyr
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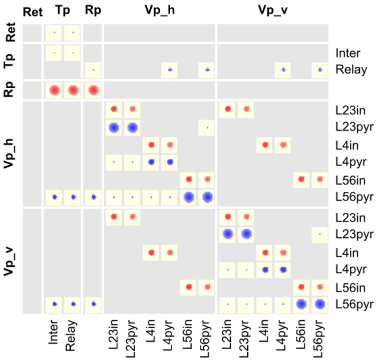
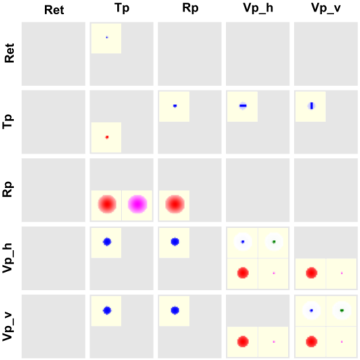
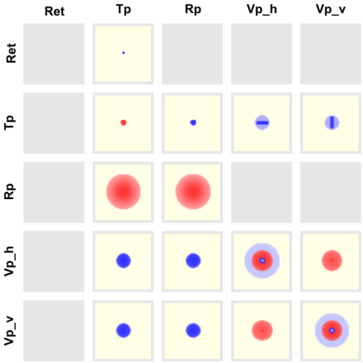
L23pyr
L4in
L4pyr
L56in
L56pyr

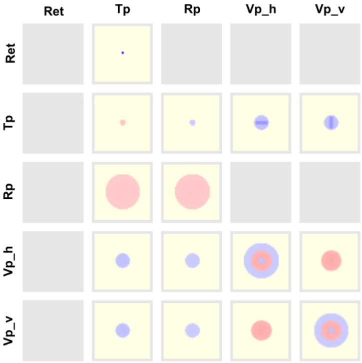
Partially Aggregated CPTs





Fully Aggregated CPTs





ConnPlotter

ConnPlotter: AutoMagic CPTs

- Python package
- Flexible generation of CPTs
- CPTs built from NEST Topology network specifications
- Use same code to build and draw models!

Example: Simple network

```
modelList = [(’poisson_generator’, ’P’, {’rate’: 10.0}),
             (’iaf_neuron’,        ’E’, {’C_m’: 200.0}),
             (’iaf_neuron’,        ’I’, {’C_m’: 150.0})]

layerList = [(’IG’, {’columns’: 40, ’rows’: 40,
                     ’extent’: [1.0, 1.0],
                     ’elements’: ’P’}),
             (’RG’, {’columns’: 40, ..., ’elements’: [’E’

connectList = [
    (’IG’, ’RG’,
     modCopy(common, {’connection_type’: ’divergent’,
                      ’synapse_model’  : ’static_synapse’
                      ’targets’: {’model’: ’E’},
                      ’mask’   : {’circular’: {’radius’:
                      ’kernel’ : 0.8,
                      ’weights’: 2.0,
                      ’delays’ : 1.0})),
    ... ]
```

Drawing the CPTs

```
import ConnPlotter as cpl
s_cp = cpl.ConnectionPattern(layerList, connectList)
s_cp.plot()
s_cp.plot(normalize=True)
s_cp.plot(mode='layer')
s_cp.plot(mode='totals')
s_cp.plot(mode='totals', normalize=True)
s_cp.plot(file='mycpt.eps')

cpt = cpl.ConnectionPattern(layerList, connectList,
      synTypes = ( ( cpl.SynType('AMPA',   1, 'red'    ),
                     cpl.SynType('NMDA',   1, 'green' ) )
                   ( cpl.SynType('Dopa', 0.5, 'orange'),
                     cpl.SynType('Sero', 0.2, 'brown' ) )
```

Creating the network

```
for model in modelList:
    nest.CopyModel(model[0], model[1], model[2])

for layer in layerList:
    exec ’%s = topo.CreateLayer(layer[1])’ % layer[0]

for conn in connectList:
    exec ’topo.ConnectLayer(%s,%s,conn[2])’ \
                         % (conn[0], conn[1])
```

Perspectives

Perspectives

- Not all kernels (even in NEST Topology) supported right now
- Non-square populations don't work 100% yet
- Non-centered projections not implemented
- Ignores boundary conditions
- Must become compatible with PyNN
- Do you like CPTs?

Collaborators

Eilen Nordlie

Marc-Oliver Gewaltig