Description and testing of networks

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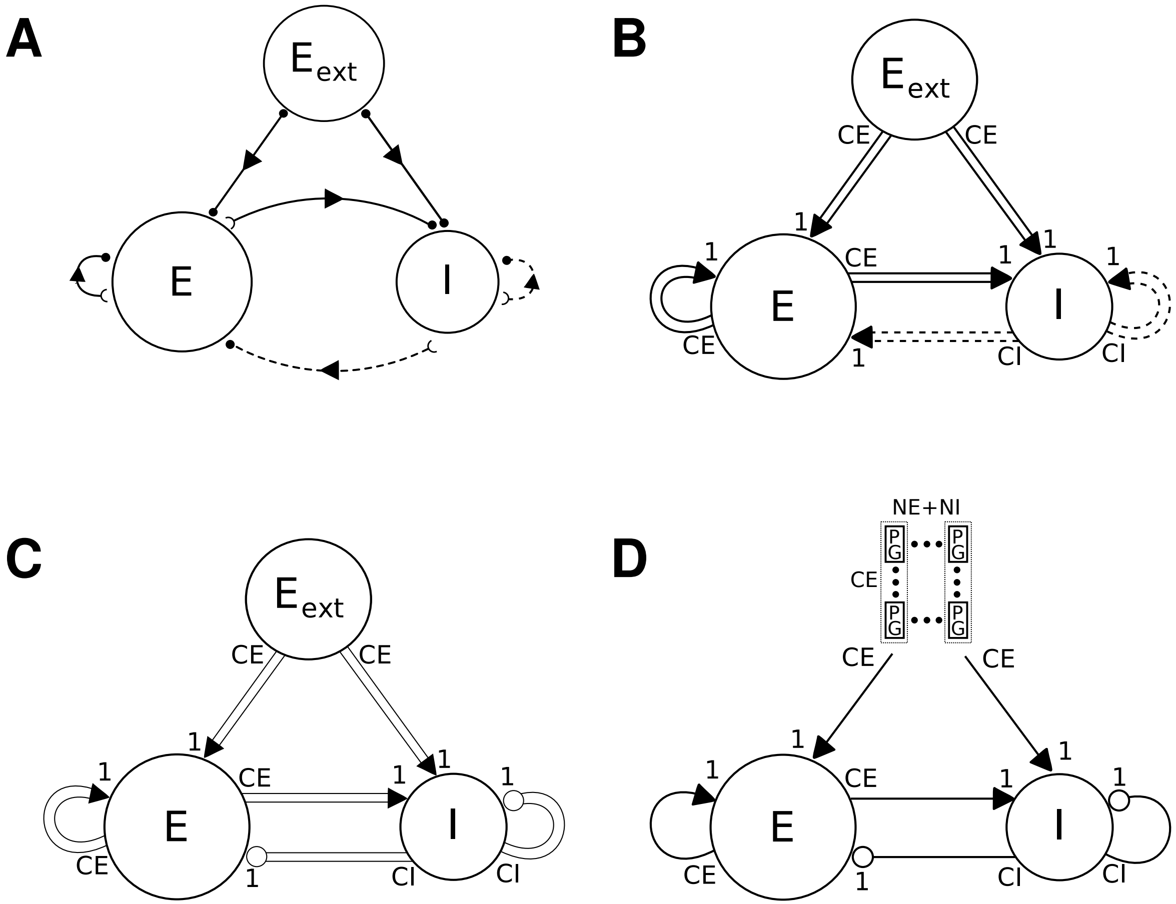
- ensure reproducibility
- improve comparability to other network models and neuroanatomy
- aid understanding of activity dynamics in complex networks
- facilitate optimal coding
- ...

Still lack of consensus of how to describe networks:

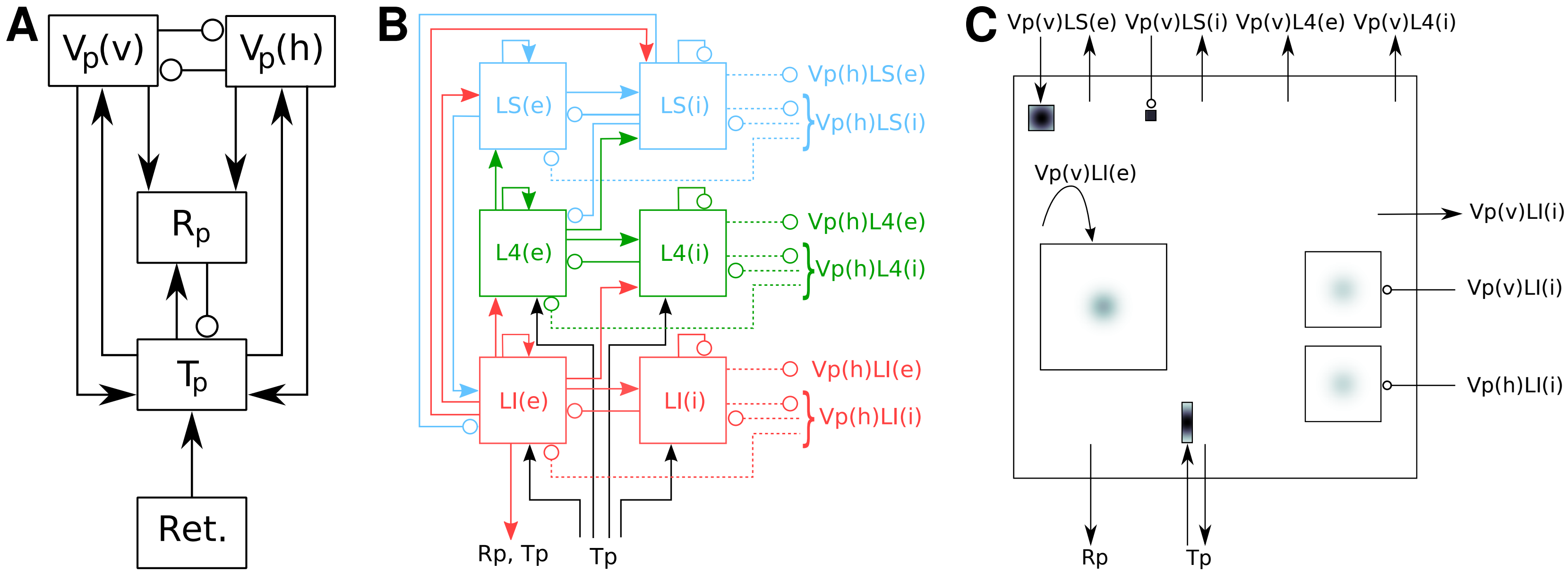
- graphically
- formally
- conceptually
- ontologically

Graphical representation:



Nordlie et al. Towards Reproducible Descriptions of Neuronal Network Models. PLoS Comput Biol 5(8): e1000456 (2009)

Graphical representation:



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Formal representation:

A	Model Summary
Populations	Eight: primary and secondary pathway, each comprising retina, thalamus (two layers), reticular nucleus, cortex (three layers)
Topology	Cartesian grids using visual-space coordinates
Connectivity	Random divergent connections described by probability kernels and cut-off masks
Neuron model	Leaky integrate-and-fire, fixed threshold, no absolute refractory time
Channel models	Slow hyperpolarizing channel
Synapse model	Conductance-based difference-of-exponentials (AMPA, $GABA_A$, $GABA_B$), additional instantaneous sigmoidal voltage dependence (NMDA)
Plasticity	—
Input	Thalamus: inhomogeneous Poisson spike trains reflecting drifting gratings; all neurons: spontaneous Poisson spike trains
Measurements	Membrane potential

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Formal representation:

C	Topology
Rectangular $8^\circ \times 8^\circ$ patch of parafoveal visual field mapped directly onto $N_\mathrm{p} \times N_\mathrm{p}$ and $N_\mathrm{s} \times N_\mathrm{s}$, respectively	

D	Connectivity
Type	Divergent connections drawn from a probabilistic kernels with cut-off masks, based on grid-distance
Kernel	$p(\vec{s},\vec{t}) = p_0 e^{-\frac{\lvert\vec{s}-\vec{t}\rvert}{\sigma}}$ (cf. [10, Tab. 3], p_0: "Max pr. of connection", σ: "Space constant")
Mask	$p(\vec{s},\vec{t}) = 0$ if $\begin{cases} \lvert s_x - t_x\rvert > \Delta_x/2 \text{ or} \\ \lvert s_y - t_y\rvert > \Delta_y/2 \end{cases}$ ($\Delta_{x,y}$: "arbor spread")
Weights	Fixed, identical for each synapse type, cf. [10, Tab. 1]
Delays	Fixed, drawn from Gaussian distribution with $\sigma = 1$ms, cut-off near 0ms implicit but not given in paper; for means see [10, p. 211, left column]

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Really formal representation: CSA

Connection Set Algebra by Mikael Djurfeldt

$$
\begin{aligned}
C &= \langle \bar{\rho} V, g, l \rangle \\
V &= \phi(\sigma_d, c) d \\
g &= g_d V + \rho N(0, \sigma_g, g_d) \\
l &= r + d/v
\end{aligned}
$$

$\rightarrow$ Mikael's talk

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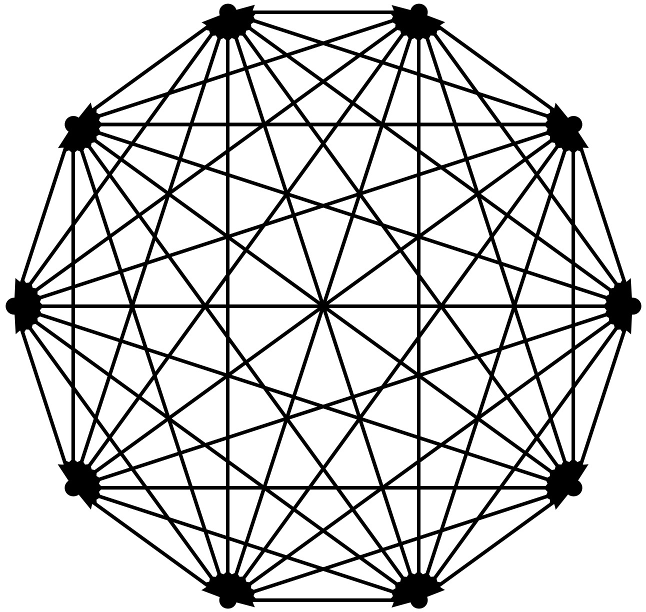

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What do we mean by the terms we use to describe networks ?

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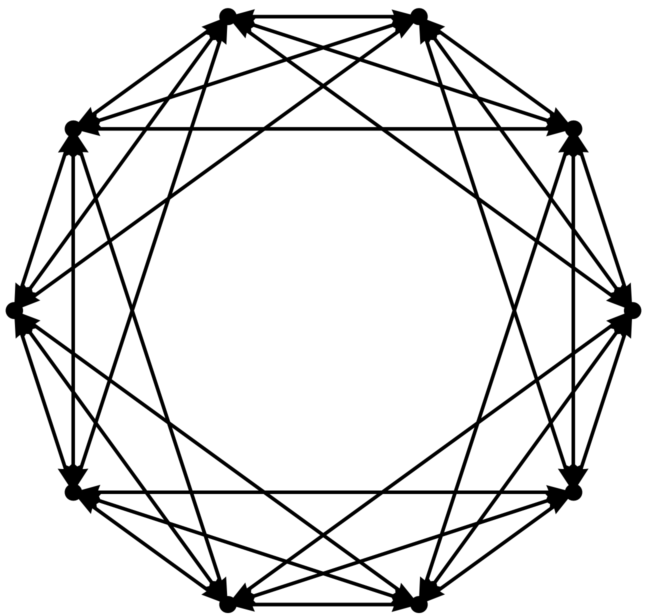
- ring

ring:



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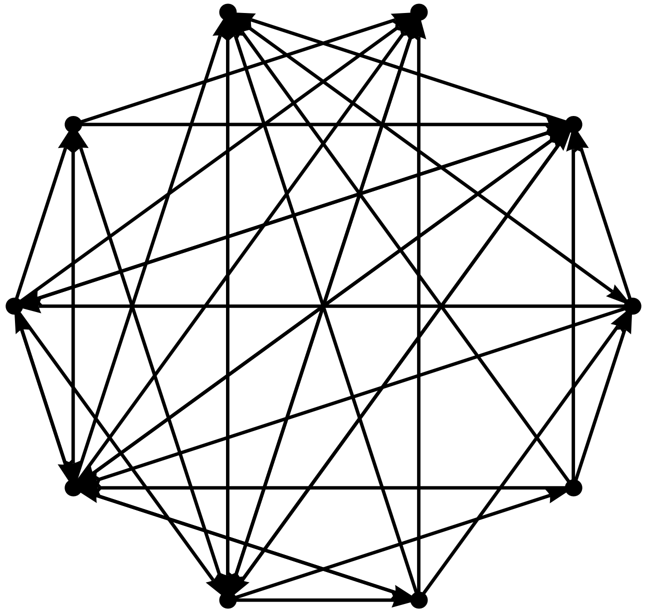
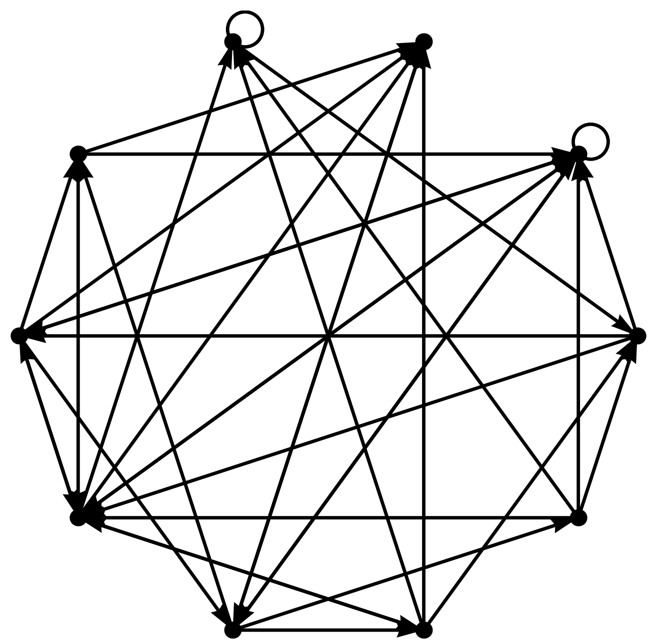


random:

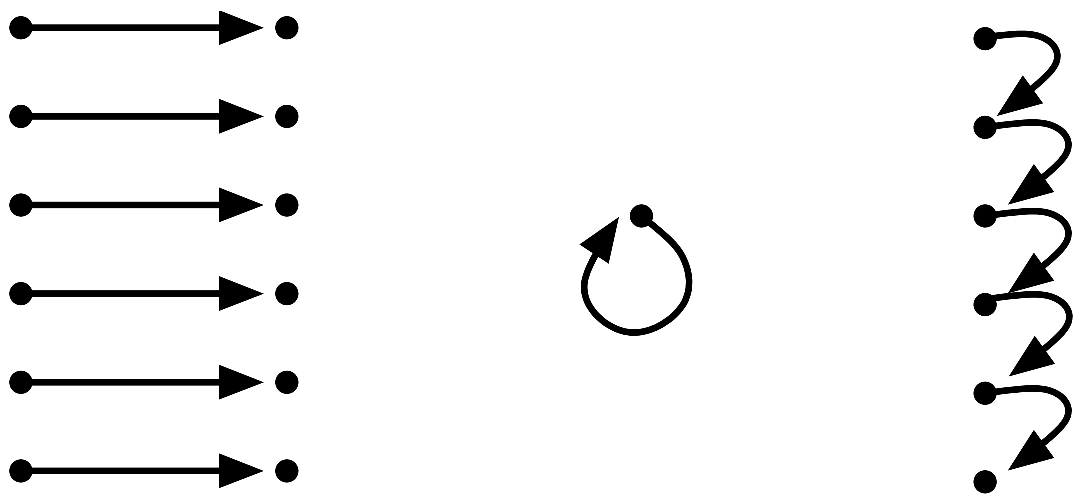


Conceptual representation:

What do we mean by the terms we use to describe networks?

- all-to-all
- ring
- random
- one-to-one?

one-to-one ?



→ Ontology, *CNO*, cf. Yann's talk

Workshop Sep 2011:
Creating, Documenting & Sharing Network Models

- started to set up a draft and plan a wiki on connectivity primitives (with Mikael Djurfeldt)
- try to systemize different terminologies used e. g. in NEST, CSA, PyNN, ... (e. g. RandomConvergentConnect vs. FanIn)
- hopefully allows for unambiguous network definitions

Some (subjective) ideas on connectivity primitives:

- work on sets of nodes and edges, i. e. *graphs*
- connectivity specifies which pairs of all possible pairs of nodes in a given set are connected by edges (aka adjacency/topology)
- connectivity primitives as 'minimal connectivity concepts'

Some (subjective) ideas on connectivity primitives:

- *connection primitive* is node-centric, i. e. defines connectivity between individual nodes
- *projection primitive* is edge-centric, i. e. defines connectivity between sets of nodes
- *graph primitive* is graph-centric, i. e. defines connectivity of entire graphs or ensembles

Some (subjective) ideas on connectivity primitives:

- connectivity primitives can be *local*, i. e. each node connects to other nodes independently of the state of the connectvity as a whole (i. e. the graph or any subset of it)

- *non-local* primitives are not independent of the connectivity of other nodes

- connectivity primitives can be *deterministic* or *probabilistic*

Possible examples for connection primitives (tbd):

- one-on-one-connection or edge ("synapse")
- self-connection ("autapse")
- one-to-many/many-to-one ("divergent/convergent")
- multi-connection ("multapse")
- random convergent/divergent (fan-in/fan-out): many-to-one/one-to-many + probability distribution

Possible examples for projection primitives (tbd):

- feed-forward all-to-all
- probabilistic (needs specification of distribution!)

Possible examples for graph primitives (tbd):

- Erdős-Rényi random graph
- Watts-and-Strogatz small world network

Values and attributes to specify connections:

- values:
  - nodes can have position, membrane potential, preferred orientation, ...
  - edges can have distance, weight, delay,...
- attributes:
  - nodes can be “excitatory”, “parvalbumin expressing”, “compartment”, “synaptic contact point”, “LGN”, ...
  - edges can be “static”, “plastic”, “current-based”, “AMPA”, ...
- establishment of connections can depend on all of these

Evaluation of probabilistic networks

– 2D spatial network example:

Embedding networks into a geometric space:

- connectivity will depend on

  - neuron distribution (uniform random, grid, non-uniform)

  - connectivity kernel (density or probability)

  - boundary conditions (open, periodic, mixture)

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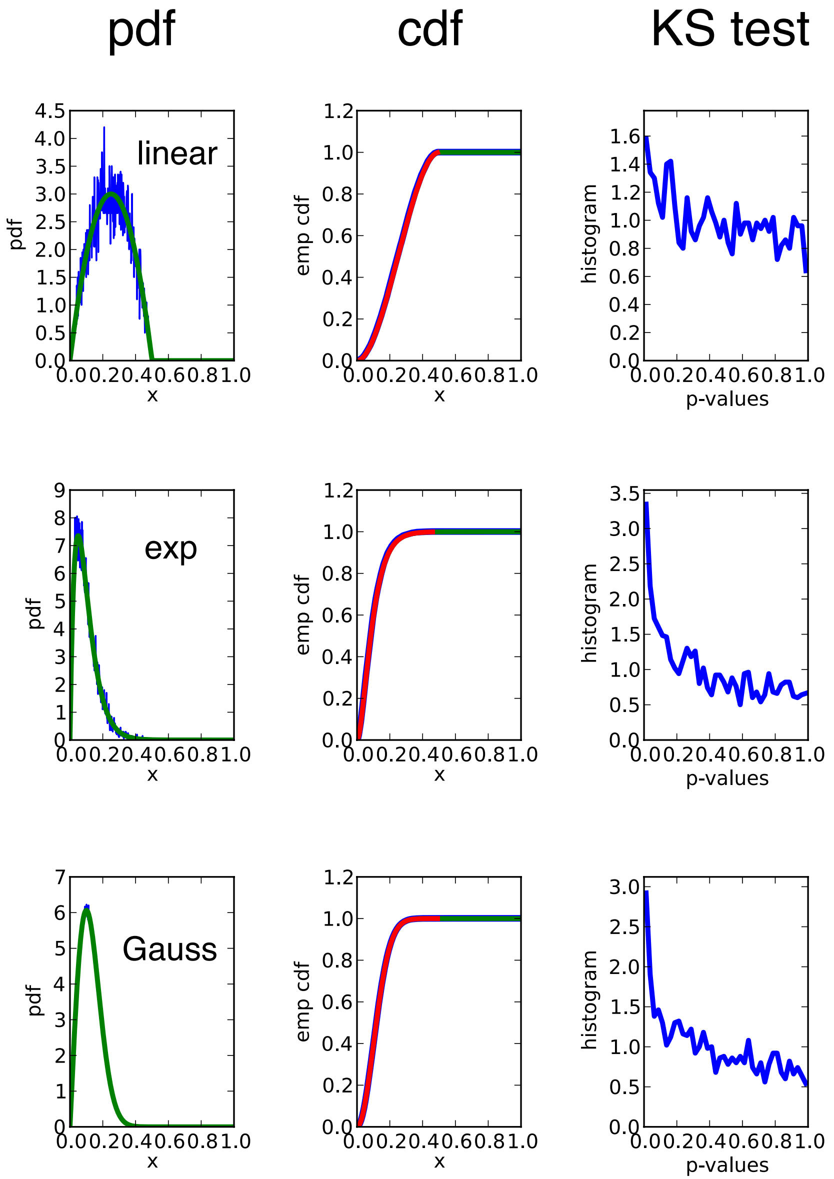
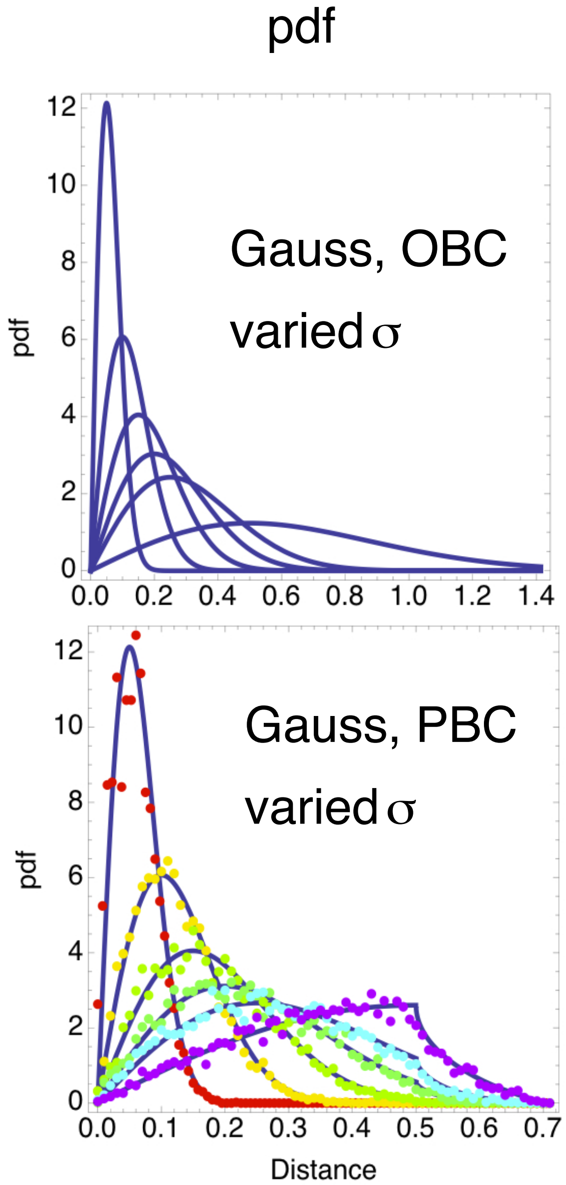
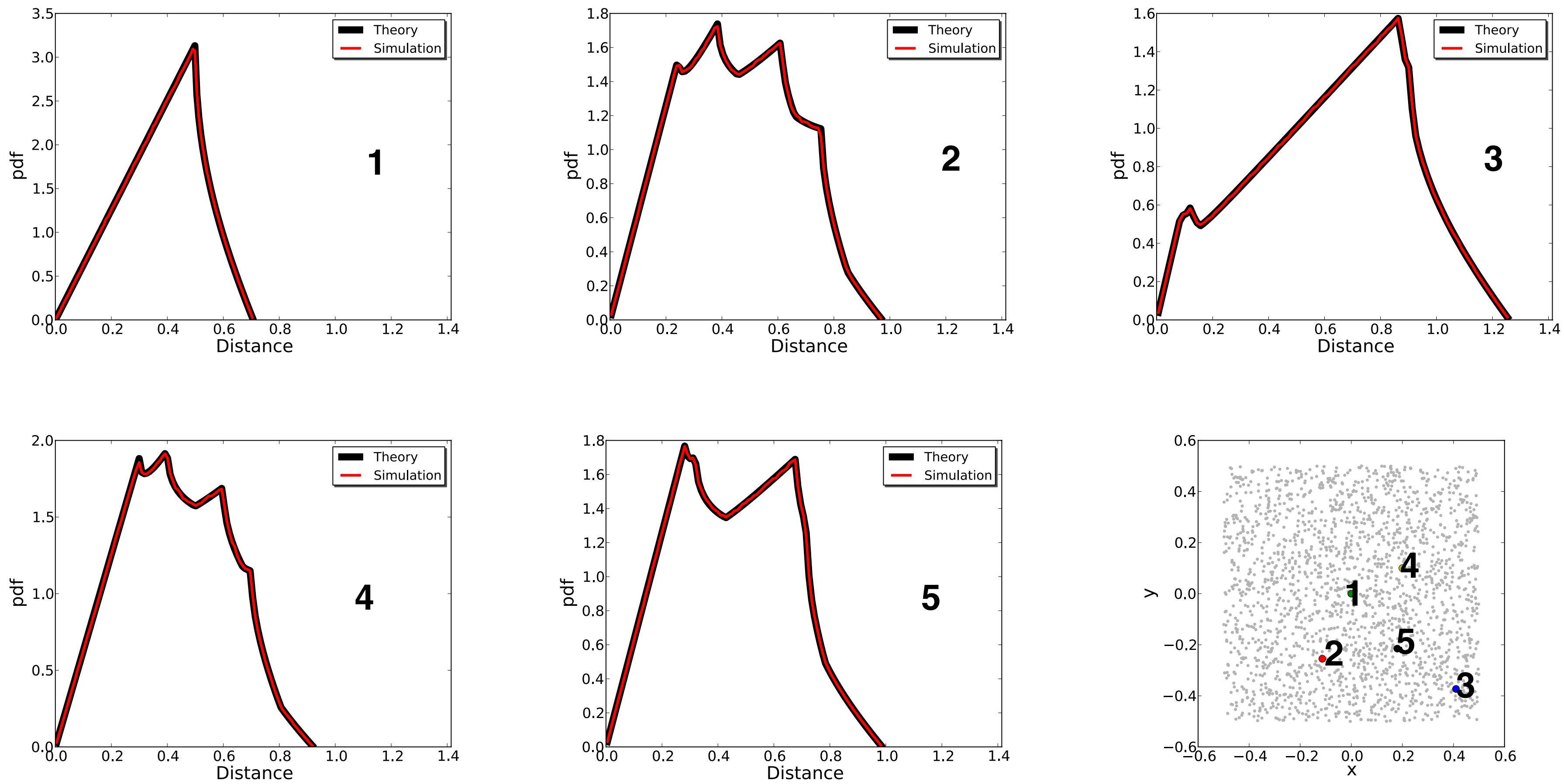
- one of the most basic features: distribution of pairwise distances

Periodic boundary conditions:

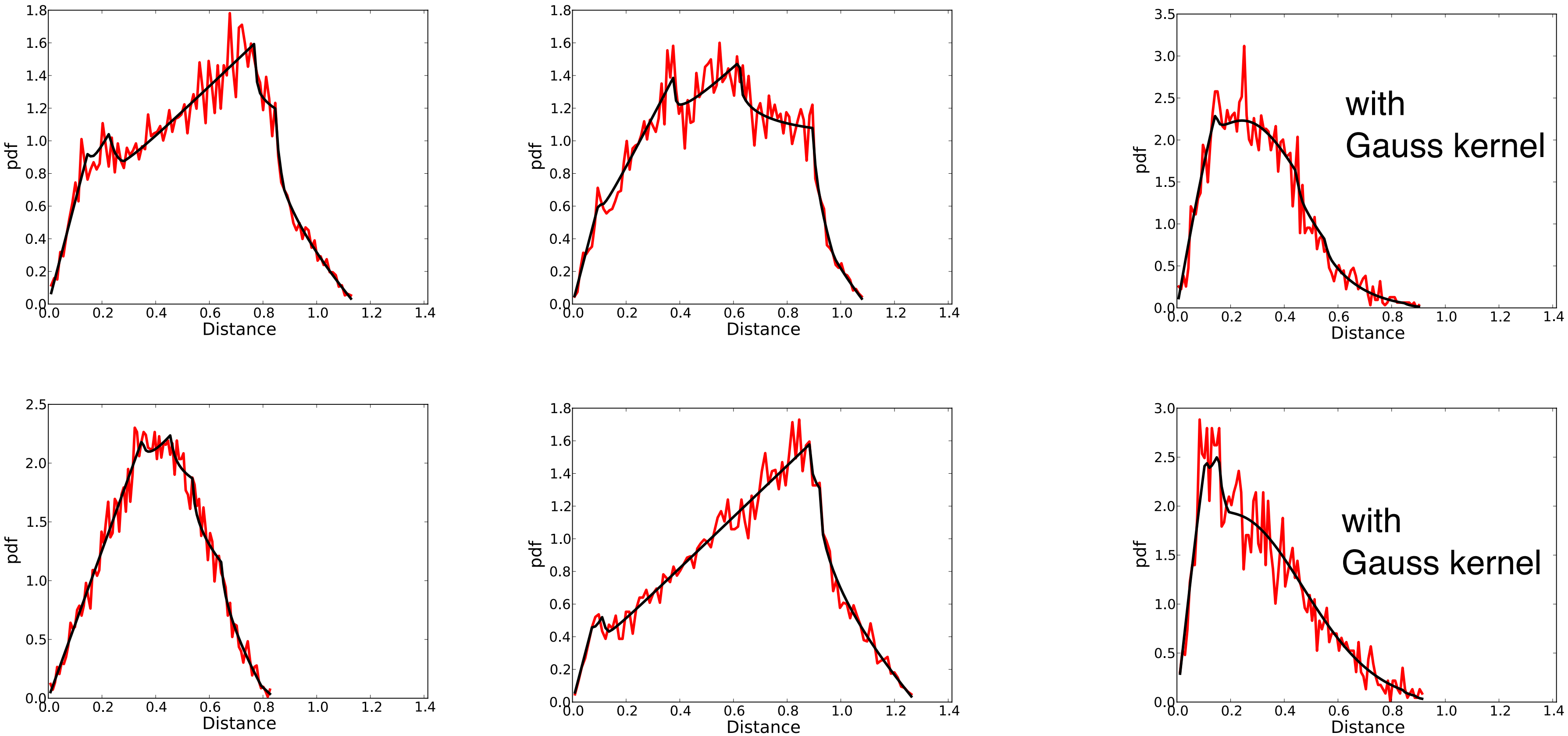




Open boundary conditions - position matters :



Finite sample size effects - the normal case:



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- which degree of description detail suffices to specify a complex network?
- when can we be sure the simulator creates the networks we think it creates?
- benchmark/common criteria for models used most often?
- how to deal with very large multi-population networks?
  (cf. however Nordlie et al., PLoS Comput Biol 5(8):e10000456 (2009))

NEW !!!

LFPy

Local Field Potentials in Python

http://compneuro.umb.no/LFPy/

Thanks!