BRIAN

http://brian.di.ens.fr

Romain Brette & Dan Goodman
Ecole Normale Supérieure
Projet Odyssée

brette@di.ens.fr
goodman@di.ens.fr

INRIA

ÉCOLE NORMALE SUPÉRIEURE
Département d'Informatique

Brian: a pure Python simulator

What is Brian for?

- Quick model coding for every day use
- Easy to learn and intuitive
- Equations-oriented: flexible

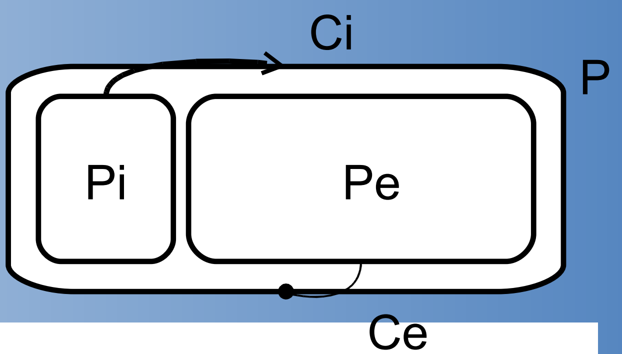
What is Brian not for?

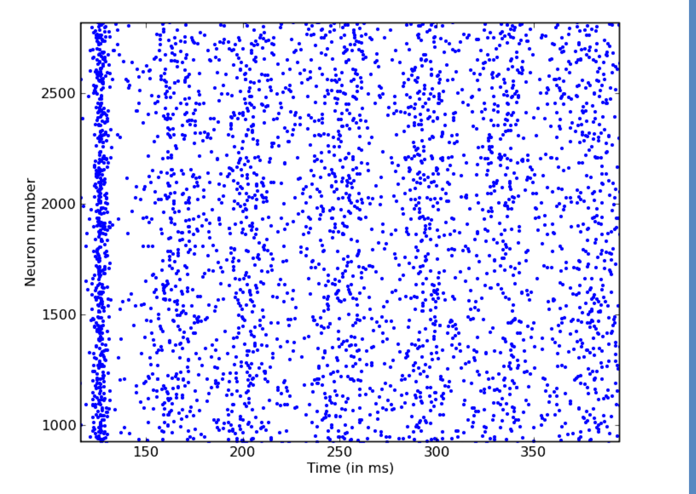
- Very large-scale network models (distributed)
- Very detailed biophysical models

Brian in action

$$\tau_m \frac{\mathrm{d}V}{\mathrm{d}t} = -(V - E_L) + g_e + g_i$$
$$\tau_e \frac{\mathrm{d}g_e}{\mathrm{d}t} = -g_e$$
$$\tau_i \frac{\mathrm{d}g_i}{\mathrm{d}t} = -g_i$$

```
from brian import *

eqs = """
dv/dt  = (ge+gi-(v+49*mV))/(20*ms) : volt
dge/dt = -ge/(5*ms) : volt
dgi/dt = -gi/(10*ms) : volt"""


P = NeuronGroup(4000,model=eqs,threshold=-50*mV,reset=-60*mV)
P.v=-60*mV
Pe = P.subgroup(3200)
Pi = P.subgroup(800)
Ce = Connection(Pe, P, 'ge')
Ci = Connection(Pi, P, 'gi')
Ce.connectRandom(Pe, P, 0.02, weight=1.62*mV)
Ci.connectRandom(Pi, P, 0.02, weight=-9*mV)

M = SpikeMonitor(P)
run(1*second)

rasterPlot(M)
show()
```



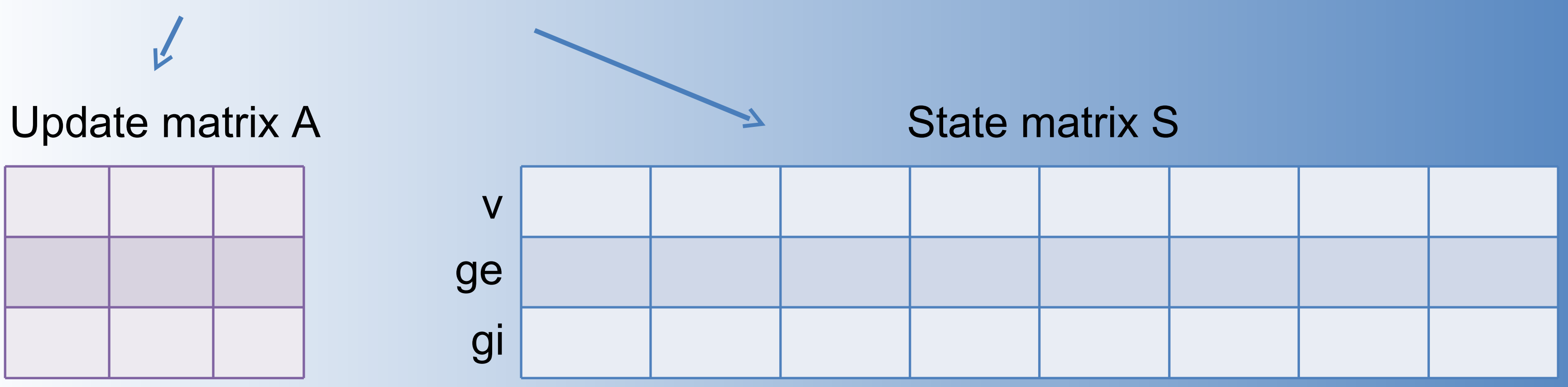


How it works

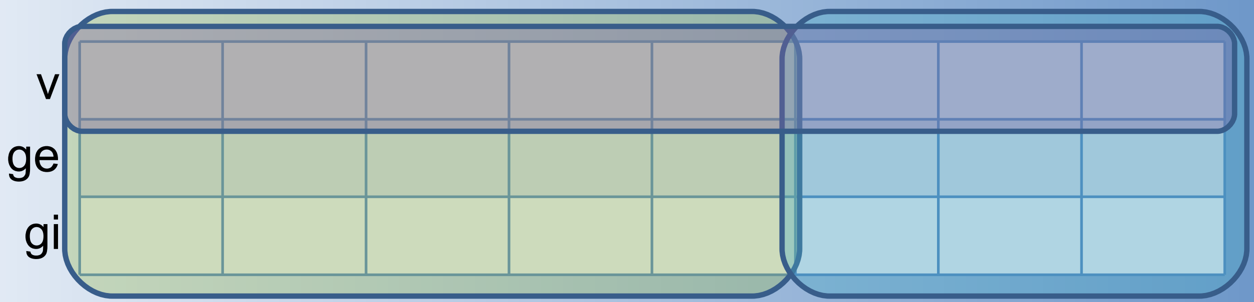
- Synchronous operations are implemented as vector operations (Scipy)
- Cost of each vector-based operation = scales as N
- Cost of interpretation = constant = negligible for large networks

Neuron groups

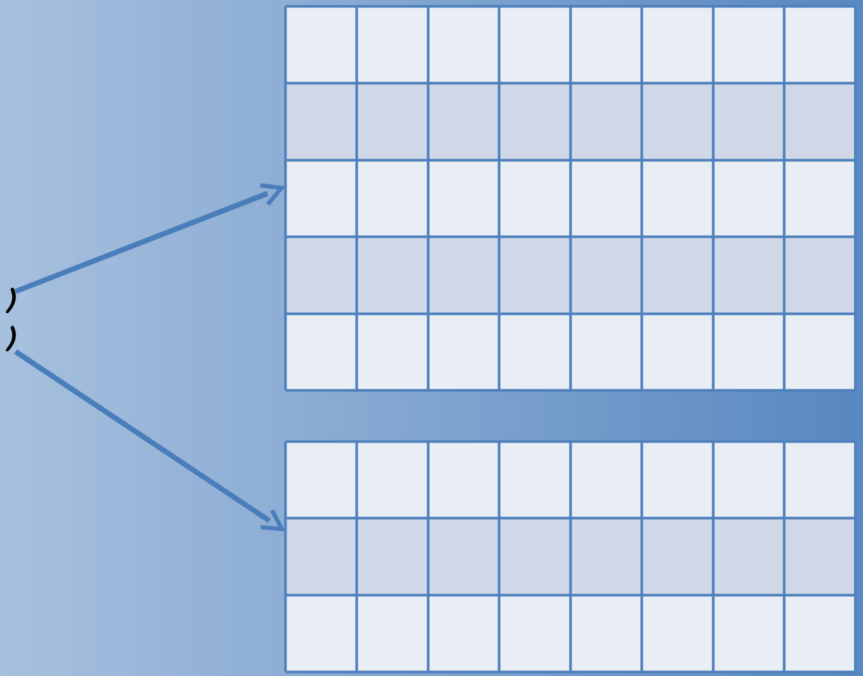
```
eqs = """
dv/dt  = (ge+gi-(v+49*mV))/(20*ms)
dge/dt = -ge/(5*ms)
dgi/dt = -gi/(10*ms)"""

P = NeuronGroup(4000,model=eqs,threshold=-50*mV,reset=-60*mV)
```



How it works (2)

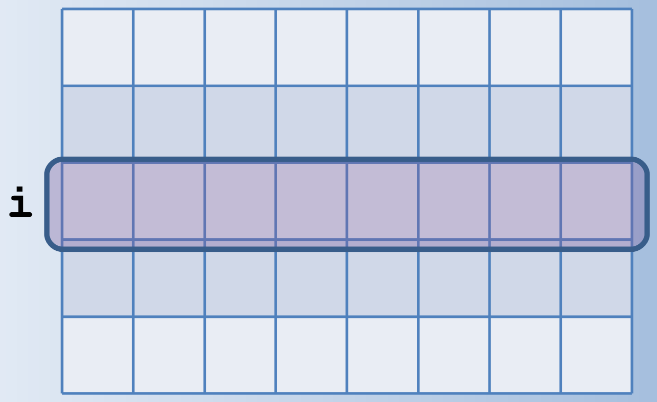



```
P.v = -60*mV
Pe = P.subgroup(3200)
Pi = P.subgroup(800)

Ce = Connection(Pe, P, 'ge')
Ci = Connection(Pi, P, 'gi')
```



How it works (3)

```
Ce.connectRandom(Pe, P, 0.02, weight=1.62*mV)
Ci.connectRandom(Pi, P, 0.02, weight=-9*mV)
```



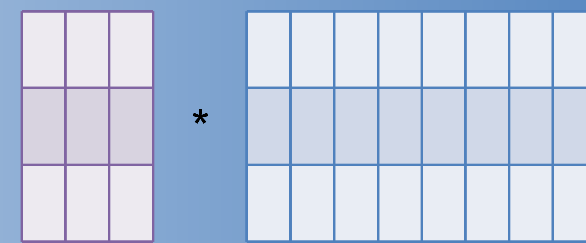
Sparse matrix (0s not stored)
(scipy.sparse.lil_matrix)

Vector-based construction:

```
for i in xrange(len(Pe)):
    k=random.binomial(m,p,1)[0]
    W.rows[i]=sample(xrange(m),k)
    W.data[i]=[value]*k
```

How it works (4)

```
M = SpikeMonitor(P)
run(1*second)
```



<u>Clock-based simulation</u>

3.Update state matrix: `S=dot(A,S)`

5.Check threshold: `spikes=(S[0,:]>vt).nonzero()[0]`

7.Propagate spikes: `S[1,:]+=W[spikes,:]`

(more complicated with sparse W)

9.Reset: `S[0,spikes]=vr`

+ user-defined operations in between

```
M.spikes+=zip(spikes,repeat(t))
```

Planned features

- STDP (close to finished)
- Gap junctions
- Using the GPU (project with GPULib)
- Automatic code generation
- Static analysis of neural networks
- Distributed simulations?
- Event-driven algorithms?
- Compartmental modelling?

How you can help...

- Improve physical units package
- Job scheduling (e.g. with Condor)
- Plotting and analysis (integration with NeuroTools?)
- User interfaces (e.g. HTML with CherryPy)
- PyNN interface
- Bug analyser (standardisation with PyLint?)
- Magic module (standardisation? Improvements?)
- Visualising networks (using graphviz?)
- Documentation tools (ReST+filters?)
- Or... get more deeply involved and contribute to core Brian features (get in touch!)

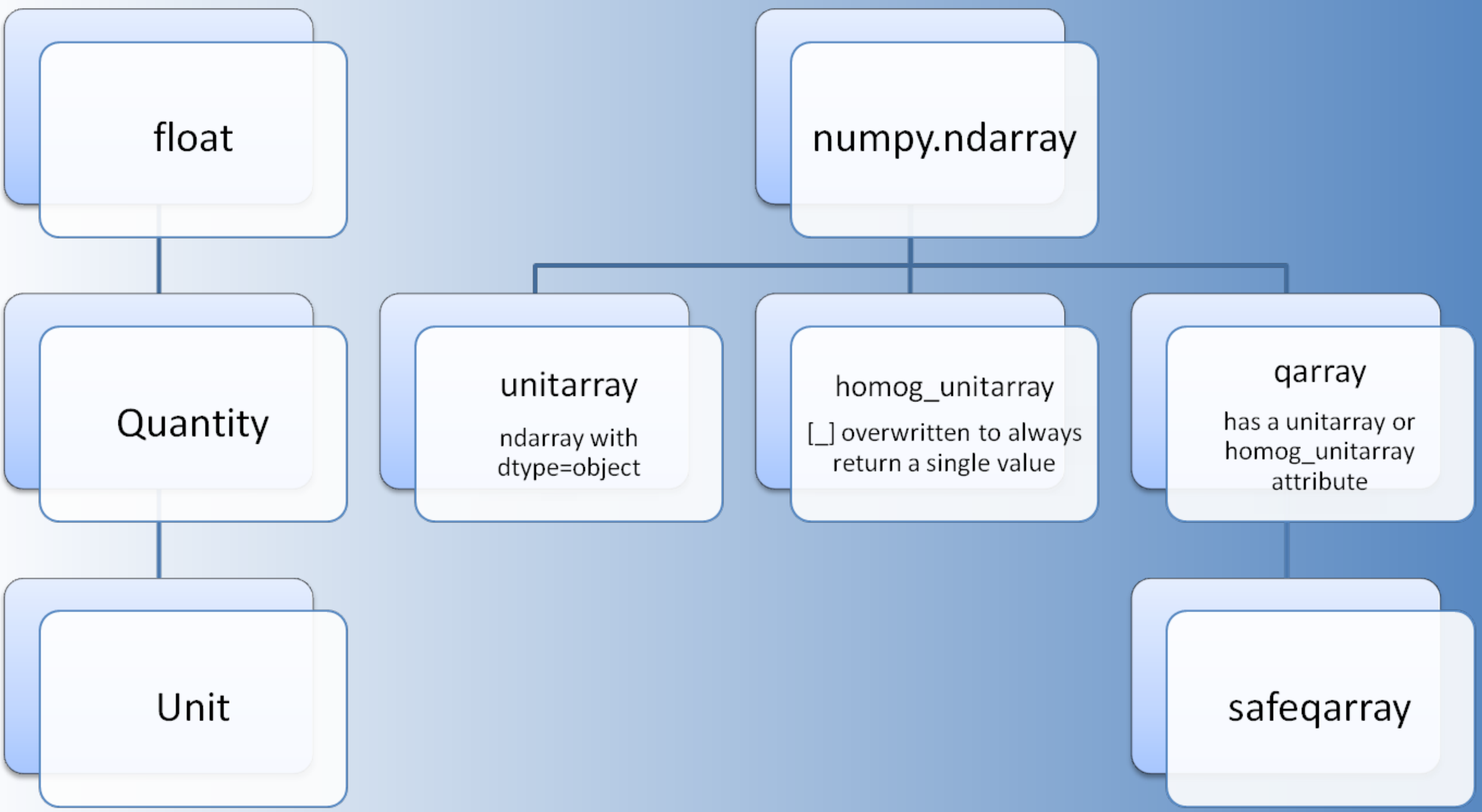
Data structures: output

- StateMonitor
  - M.times = qarray of length num steps with units of time
  - M[i] = qarray of length num steps with units of recorded state variable for neuron i
- SpikeMonitor
  - M.spikes = Python list of pairs (i, t) [also used as an input data structure]
- PopulationRateMonitor
  - M.times = qarray of length num bins, giving the left edge of the interval, units of time
  - M.rate = qarray of corresponding rates in Hz

Data structures: input

- Physical units
  - Quantity (derived from float)
  - qarray (derived from numpy.ndarray)
- Equations
  - dV/dt = (-V + V0 + a*sin(b*t))/tau : volt [diff. equation]
  - w = V*V : volt2 [equation]
  - u = V [alias]
  - V0 : volt [parameter]
- NeuronGroup of N neurons
  - G.varname = qarray of length N with units of that state variable (defined in Equations)
- SpikeGeneratorGroup
  - spiketimes can be a list of pairs (i,t), or a function returning a list of pairs, or a Python generator
- MultipleSpikeGeneratorGroup
  - spiketimes is a list of sequences (t0, t1, t2, ...), one for each neuron

Units in Brian: classes



Units in Brian: functions

- Some new versions of numpy functions, mostly just wrappers, e.g. rand(n)=qarray(numpy.rand(n))
- Ufuncs: dimensionally consistent arithmetic and many array functions implemented via ufuncs mechanism by overriding the behaviour of qarray.__array_wrap__
- qarray methods: other numpy functions such as mean, std, var, etc. implemented as methods

Units in Brian

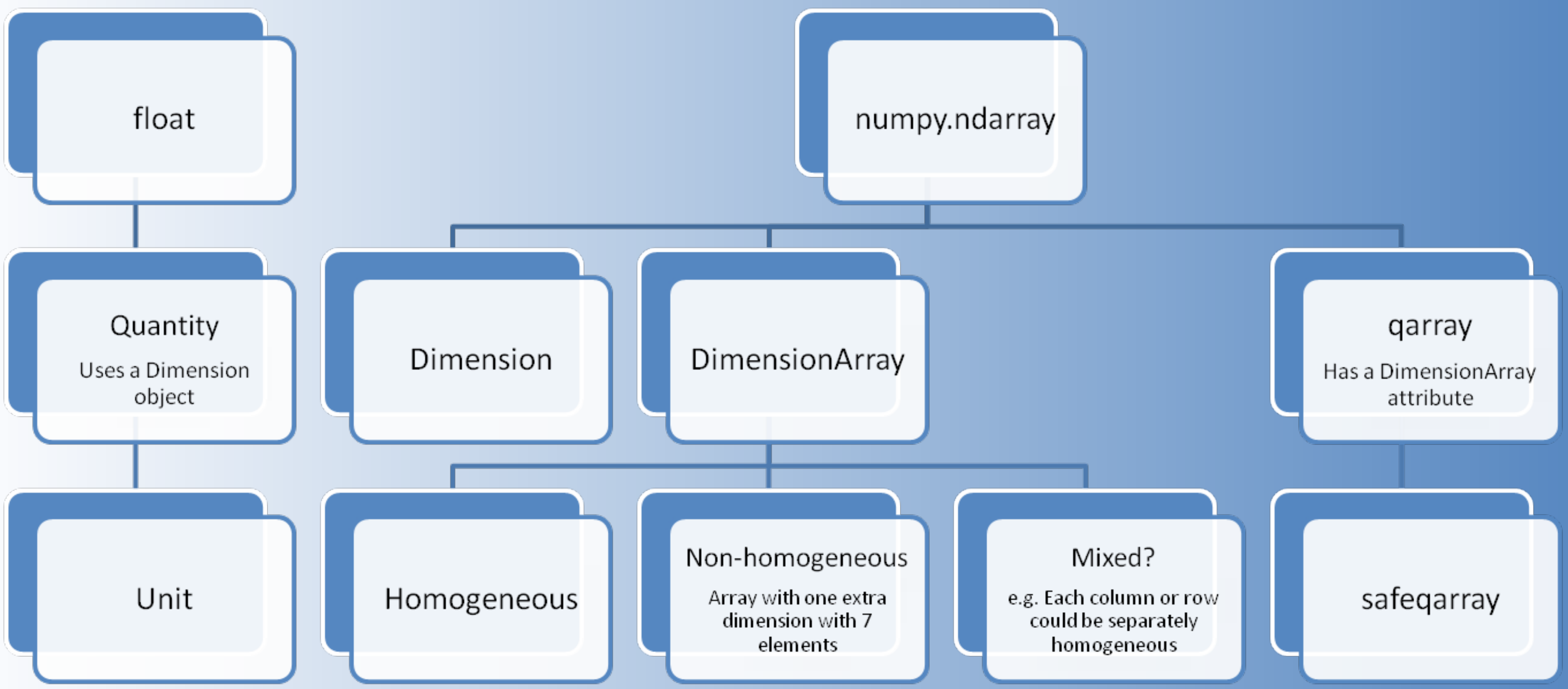
Advantages

- Flexible system
- Written in pure Python so will run on any platform
- Transparent: in many cases, works as if you were just using numpy except with units

Disadvantages

- Slow, unusably so in the case of arrays with non-homogeneous units
- Doesn’t work transparently with numpy arrays, e.g. array(...)*kg=array(...) not qarray(...)

An alternative system for units



Ideas for alternative system

- Implement Dimension operations by relations like dim(xy)=dim(x)+dim(y) and use numpy. Potentially much faster.
- Implement code in C/C++ rather than pure Python.
- Mixed homogeneity of units more flexible but difficult to code.
- Could fork units off as a separate project, maybe even try for inclusion in numpy at some point.
- Possibly better to just have homogeneous units and safeqarray – less ambitious, easier, but similar to existing physical units packages.