EEGcode: Introduction to simulations for various continuum brain models

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What is EEGcode ?

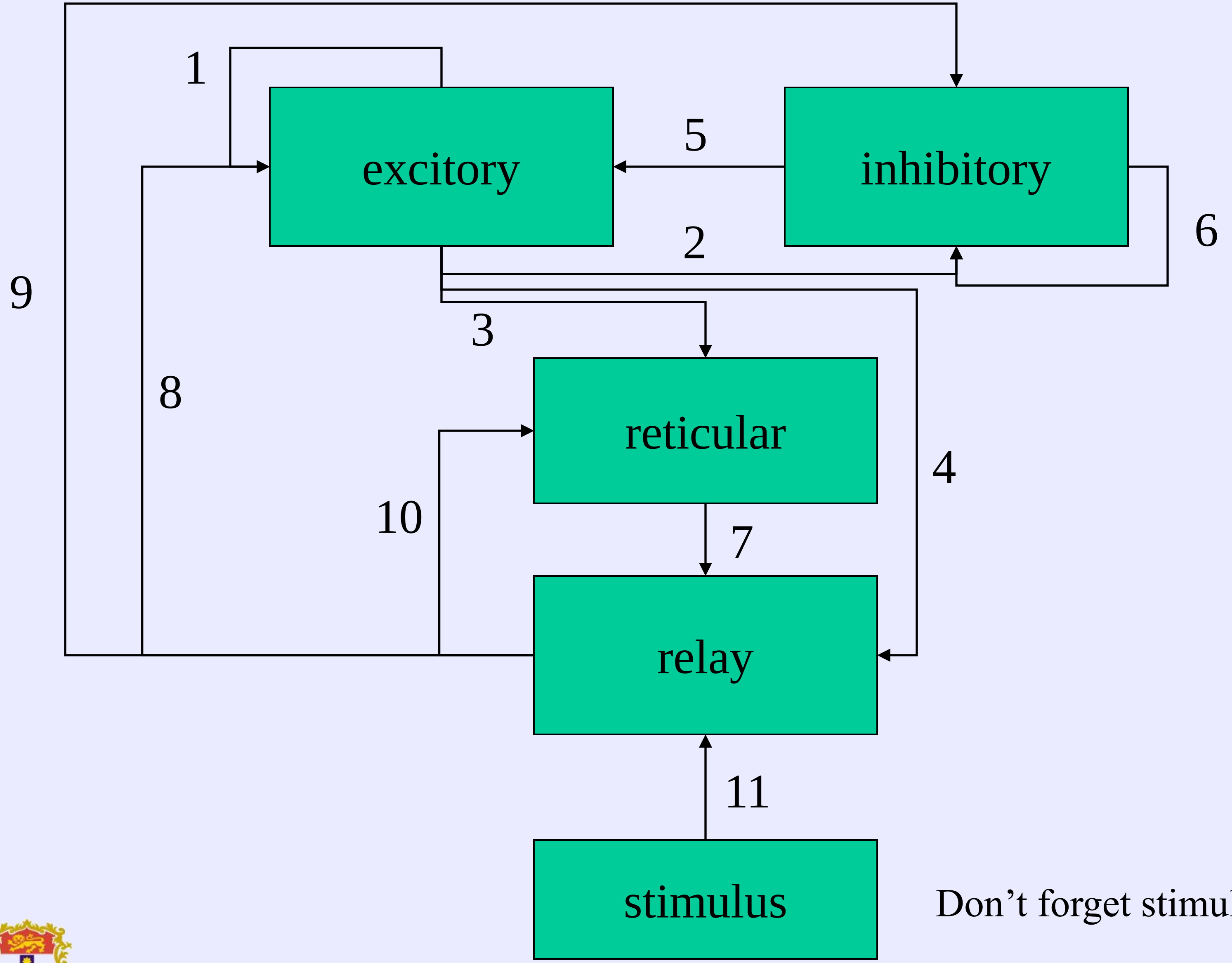
- EEGcode allows integration of a variety of different forms of continuum models of the types studied in the Brain Dynamics group.
- The diverse number of models that can be integrated means it is important to carefully specify the exact form of the model being studied.
- EEGcode is written in a object orientated form allowing the simulated model to be assembled out of blocks much like Lego.
- A side effect of the generality of the models is that for any particular model numerous parameters are equal since a number of blocks are the same but each is specified separately.

Types of models integrated by EEGcode

Models to be integrated include the following component parts:

- Firing Response: Sigmoid which converts from soma voltage to firing rate.
- Propagator response: A wave equation, patchy propagator set of wave equations or simple mapping allowing spreading of firing to neurons in another population
- Coupling response: Synaptic coupling via weights either constant in time or following Clearwater/Rennie neuromodulator evolution equation.
- Dendritic Response: Each different population synapsing onto a dendrite has its own dendritic response equation. This is a generalization to most Brain Dynamics group models where all the synapsing onto populations have the same properties (α,β).

Step 1: Draw model and label connections



Don’t forget stimulus populations

Getting the code

- The latest stable distribution of the code is kept in the directory /import/suphys2/peter/stableEEGcode. Romesh and Sue are going to put it into “Track” in Jan-Feb 2011
- On linux/Mac OSX boxes the code can be compiled with the script ‘ccc’.
- The code has been compiled on a number of other systems e.g. Win. Changes to script are minimal due to one line compilation and no complex Makefile.
- An OpenMP version of the code exists for running on multicore machines. It scales sublinearly
- To test the code run with command ‘eegcode write defaults’ which writes a default config file and runs the corresponding simulation.

Writing eegcode.conf

- Configuration and model choice is through the ‘eegcode.conf’.
- A default eegcode.conf file is available by running code with command line ‘eegcode write defaults’ a Robinson/Rennie corticothalamic model.
- The broad outline of the eegcode.conf file is:

1) Define the global parameters - nodes and time scale.
2) Define the connectivity matrix.
3) Specify types of ‘blocks’ you will be using.
4) List each population’s properties - Firing response and list of dendritic responses from other neurons.
5) List each propagator’s properties.
6) List each coupling responses properties including coupling output.
7) Describe output data requested.

Global parameters and connectivity

- Within the code ‘nodes’ are discretized spatial coordinates. Although the volume of a spatial cell is different for each population, the same number of nodes must be in each population.
- As spatial dimensions are implemented are wrap around ‘torus’ a minimum of 4 nodes for spatial propagators.
- Connectivity matrix can be read directly from diagram, Rows are TO, columns are FROM.

Specifying types of blocks

- Delays such as corticothalamic delay require efficient storage of firing rates. The maximum number of time steps that each Q_a requires should be specified.
- In order that the code knows which kinds of propagators and coupling ‘blocks’ you require these are specified at this point.

Population parameters

- Two types of population: 1) Normal 2) Stimulus
- A stimulus population has no connections arriving to the population. The connection matrix determines this property.
- Normal population has initial firing rate $Q(0)$ and sigmoidal parameters (θ,σ,Q_{max}). Following is a list of dendritic parameters for each population synapsing onto this population. Parameters include (α,β) plus initial dendritic subpotentials $V_{ab}(0)$. These can be calculated via $V_{ab}(0) = \upsilon\, Q_b(0)$
- Stimulus population parameters are defined by numerical 'mode' numbers. Possible stimulus modes include constant and pulse stimulus and a variety of Gaussian noise types. New stimulus patterns are extremely easy to add (timeseries.cpp).

Propagator parameters

- Six types of propagator 1) Mapping 2) Waveeqn 3) Eqnset 4) Harmonic 5) WaveqnRect 6) EqnsetRect.
- All propagators allow a time delay term τ_{ab} which maybe an array.
- Mapping is the simplest propagator - mapping Q from a particular spatial node to its counterpart in the other population e.g. intrathalamic connections in Robinson/Rennie corticothalamic model.
- WaveEqn is the delayed source wave equation propagator with parameters (γ, r, τ_{ab}). Use Harmonic if no spatial variation
- Eqnset is a set of wave equations implementing the model in the Robinson patchy propagator paper.
- Both WaveEqn & Eqnset require definition of spatial scale for a population (Δx). This must satisfy the Courant condition which cannot always be caught by the code.

$$\Delta t/\Delta x < \sqrt{2} / r_e \gamma_e$$

Coupling parameters

- Three types of synaptic coupling 1) Simple 2) Modulate 3) Coupleplast (stub).
- Simple coupling is just a constant synaptic strength product

$$V_{ab} = \upsilon_{ab}\, \varphi_{ab}$$

- Inhibitory couplings are implemented by negative υ_{ab}.
- Modulate is the Rennie/Clearwater neuromodulator evolution equation with parameters (υ_{zero}, υ_{scal}, μ, λ, k).
- Similar to stimulus populations, modulated coupling allows a number of ‘modes’ for varying the underlying neurotransmitter.
- To follow evolution of synaptic strength output parameters are given immediately. The results appear in a file ‘eegcode.synaptout.n’ where n is the index of the coupling.

Output data and Restarting

- Data is output to ‘eegcode.output’
- The output data can be any φ within a propagator.
- Individual spatial node points for any φ can be output or all the spatial nodes for a propagator can be output via the Single/All switch.
- The output format is designed to be importable in both IDL and Matlab in a single command after the header has been processed.
- Matlab scripts for grabbing and analysing output data are available in matlabroutines subdirectory.
- The ‘eegcode.dump’ file is information for restart the simulation from where it finished.