INFORMATION ABOUT THE MODEL

This directory contains the Neuron code for the CA1 pyramidal cell model and the experiments described in:

1. **Poirazi, P. Brannon, T. & Mel, B.W.** Arithmetic of Subthreshold Synaptic Summation in a Model CA1 Pyramidal Cell. In Press, *Neuron* , February 2003.
2. **Poirazi, P. Brannon, T. & Mel, B.W.** Online Supplement: About the Model. In Press, *Neuron* , February 2003.
3. **Poirazi, P. Brannon, T. & Mel, B.W.**Pyramidal Neuron as 2-Layer Neural Network. In Press, *Neuron* , February 2003.

Following is a brief overview of the contents of this directory:

1. lib: This directory contains all the library functions used for the setup of the CA1 model cell as well as functions used in the experiments. Each of the functions is described in detail within the respective .hoc file. Briefly:

File name	Function description
basic_graphics.hoc	creates a new graphical display and allows printing of graphs to eps
basic-graphics.hoc	creates a different graphical display and allows printing of graphs to eps
choose-secs.hoc	used to select dendritic sections to be used in experiments
current-balance.hoc	used to balance the membrane potential to v_init (= -70 mV)
cut-sections.hoc	specifies the number of segments in all sections
deduce-ratio.hoc	used to deduce the NMDA/AMPA conductance ratio for various cell compartments
find-gmax.hoc	used to deduce the maximum AMPA conductance value at any location along the cell, such that a single current pulse will give rise to approximately 5mV local depolarization
GABA_shiftsyn.hoc	used to create random Poisson stimulation trains for GABA_A and GABA_B synapses stimulated
GABA_shiftsyn_bg.hoc	used to create random Poisson stimulation trains for GABA_A and GABA_B synapses firing in the background
map-segments-to-3d.hoc	used to define x,y,z coordinates for each section so it can be displayed in 3-D
maxmin.hoc	used to calculate the maximum and minimum values in a set
newshiftsyn.c	c-code that generates Poisson trains to be used for synaptic stimulation
salloc.hoc	used to place AMPA, NMDA, or GABA synapses on specific locations and estimate their conductances
shiftsyn_initA.hoc	used to create random Poisson stimulation trains for AMPA and NMDA synapses stimulated
shiftsyn_init_bg.hoc	used to create random Poisson stimulation trains for AMPA and NMDA synapses firing in the background
spike-count.hoc	used to measure spikes, i.e. the number of times the voltage is above a predefined threshold
tune-epsps.hoc	used to calculate the AMPA conductance values of any AMPA/NMDA synapse such that a single pulse stimulus gives rise to a 5mV local depolarization at every synapse location along the cell
vector-distance.hoc	used to calculate the distance of a point of interest from a reference point (ie, soma), given an apex point
verbose-system.hoc	used to execute system commands

2. morphology: This directory contains the morphology of the cell as well as various lists of dendritic compartments used in the model setup and the experiments (files are in subdirectory n123). Following is a brief description of the directory contents:

File name	Function description
apical-non-trunk.hoc	makes a list with all sections NOT on the apical trunk
apical-tip-list.hoc	makes a list with 24 primary oblique dendrites
apical-tip-list-addendum.hoc	makes a list with 14 additional oblique dendrites
apical-trunk-list.hoc	makes a list with all sections on the apical trunk
axon-sec-list.hoc	makes a list with all sections in the axon
basal-paths.hoc	makes a set of lists, each containing the basal sections that form a continuous path: starting from the section attached to the trunk and ending at the basal tip section.
basal-tree-list.hoc	makes a list with all dendritic sections in the basal tree
cell.hoc	creates the raw cell morphology by connecting all sections
cell-analysis.hoc	loads all morphology-related files and templates to be used in the experiments to follow.
gabab-gabaa-uniform-ration.hoc	defines the GABA_B/GABA_A conductance ratio for various compartments
n123.hoc	connects the sections to create the cell morphology described in cell.hoc
nmda-ampa-ratio.hoc	defines the NMDA/AMPA conductance ratio for various compartments
oblique-paths.hoc	makes a set of lists, each containing the oblique sections that form a continuous path: starting from the section attached to the trunk and ending at the apical tip section.
peri-trunk-list.hoc	makes a list of all dendritic sections directly attached to the apical trunk
soma-list.hoc	makes a list with somatic compartments

3. template: This directory contains a few files that define templates used in the model setup and experiments. Templates are described in the .hoc files. Briefly:

File name	Template description
BasalPath.hoc	template for a Basal Path list. Path starts at the section attached to the trunk and ends at the basal tip section
EPSPTuning.hoc	template to store the EPSP tuned AMPA conductance value for each location along a compartment (used with /lib/tune-epsp.hoc)
ExperimentControl.hoc	template with experiment specific parameters to ensure that experimental variable bindings are not confused with neurophysiological variable bindings
ObliquePath.hoc	template for a Oblique Path list. Path starts at the section attached to the trunk and ends at the oblique tip section
RangeRef..hoc	template for a reference pointer to the currently accessed section, at a specified location
SynapseBand.hoc	template for creation of a group of sections selected at random within a specified region and placement of synapses on selected sections.

4. mechanism: This directory contains all membrane mechanisms used in the cell model.

File name	Function description
cad.mod	Calcium pump and buffering mechanism
cagk.mod	Calcium activated mAHP K+ channel.
cal.mod	LVA L-type Ca++ channel used in somatic and proximal dendritic regions
calH.mod	HVA L-type Ca++ channel used in distal dendrites to account for distally restricted initiation of Ca++ spikes
car.mod	MVA R-type Ca++ channel used in distal dendritic regions, together with calH.mod, to account for distally restricted initiation of Ca++ spikes
cat.mod	HVA T-type Ca++ channel used in somatic and dendritic regions
h.mod	h-current
hha_old.mod	HH channel that includes both a sodium and a delayed rectifier channel and accounts for sodium conductance attenuation. Used in all BUT somatic and axon sections.
hha2.mod	HH channel that includes both a sodium and a delayed rectifier channel and accounts for sodium conductance attenuation. Used only in soma and axon sections
kadist.mod	K+ A channel that accounts for Hoffman et al 1997 distal region kinetics used only in locations > 100 microns from the soma
kaprox.mod	K+ A channel that accounts for Hoffman et al 1997 proximal region kinetics used only in locations < 100 microns from the soma
kca.mod	Slow Ca++-dependent potassium current
km.mod	Slow, noninactivating, potassium channel with Hodgkin-Huxley style kinetics. Based on I-M (muscarinic K channel)
nap.mod	Na persistent channel used in distal oblique dendrites to assist Ca++ spike initiation.
somacar.mod	MVA Ca++ R-type channel used in somatic regions. It has lower threshold for activation/inactivation and slower activation time constant than the same mechanism in dendritic regions
gabaa.mod	model of GABAa receptors
gabab.mod	model of GABAb receptors
glutamate.mod	model of AMPA receptors
Nmda.mod	model of NMDA receptors

5. experiment: This directory contains a selected set of experiments as described in the aforementioned publications. Within each subdirectory, the *.hoc files contain the NEURON code for the experiment while the run_* files are the executables used by the user to run the experiment. Each experiment is described in detail in the respective .hoc files. Briefly:

Experiment directory name	*Experiment description*
tune-synapses	Code for tuning the AMPA/NMDA conductances of a synapse placed on any possible location on the cell such that a local single pulse stimulation will result in 5mV local depolarization. For tuning, the NMDA conductance for each position is calculated using the NMDA/AMPA ratio parameter provided by the user in /morphology/n123/nmda-ampa-ratio.hoc

spike-train-attennuation	Code for (1) Back-propagating Action Potential generation (bpap.hoc) with somatic or dendritic stimulation and (2) somatic/dendritic single trace generation (Hofman_traces.hoc) under control, A-current blockade and Ca++ current blockade. The aim of this experiment is (1) to ensure that BPAPs behave similarly to biophysical data that differentiate between somatic and dendritic stimulation as seen in Spruston et al, 1995 and Golding eta al 1999 and (2) to ensure that cell response to short stimuli under control, a-current and Ca++-current blockade resemble biophysical data provided by Hofman et al 1997. The experiment is used to generate figure 2 in Poirazi, P. Brannon, T. and Mel, B.W. 'Online Supplement: About the Model.'
hyperpolarization-current	This experiment is used to study the effect of h-current on (1) input resistances and (2) propagation of hyperpolarizing voltage traces at the somatic and dendritic regions and to ensure that model responses comply with physiological findings provided by Magee 1998. The experiment is used to generate figure 1 in Poirazi, P. Brannon, T. and Mel, B.W. 'Online Supplement: About the Model.'
single-shock	This directory contains code for the Cash and Yuste 1999 validation experiments shown in Poirazi, P. Brannon, T. and Mel, B.W. 'Arithmetic of Subthreshold Synaptic Summation in a Model CA1 Pyramidal Cell., figures 1 and 2. It includes code for single pulse stimulation of two synaptic stimuli (a) individually and (b) in combination. The stimuli are placed either on two trunk sections (Trunk.hoc, Trunk_all.hoc) or within a single oblique dendrite (Apical_Tips.hoc). The aim of this experiment is to show that the model cell performs the same kind of synaptic integration for single pulse stimuli as the Cash and Yuste 1999 paper shows.
single-branch-potency	This directory contains code for the generation of figures 3 and 4 in Poirazi, P. Brannon, T. and Mel, B.W. 'Arithmetic of Subthreshold Synaptic Summation in a Model CA1 Pyramidal Cell' as well as figure 3 in Poirazi, P. Brannon, T. and Mel, B.W. 'Pyramidal Neuron as 2-Layer Neural Network.' This includes code for 50Hz or single shock stimulation of two groups of synapses in apical obliques where synapses are stimulated (a) individually and (b) in combination. Stimulated synapses can be within the same oblique (A_feq.hoc, A+Bfreq.hoc, A_shock.hoc,) or in two different obliques (A+Cfreq.hoc, A+Cshock.hoc). The aim of this experiment is to show that synaptic integration is different for single pulse vs. high frequency stimulation and for within versus between side branch stimulation.
cluster-dispersion	This directory contains code for the generation of figures 2, 5 and 6 in Poirazi, P. Brannon, T. and Mel, B.W. 'Arithmetic of Subthreshold Synaptic Summation in a Model CA1 Pyramidal Cell.' This includes code for 50 Hz stimulation of a fixed number of excitatory synapses (32, 35, 36, 40, 45, 48, 49, or 63), which are distributed on apical obliques in increasingly clustered form. Spike rate for different degrees of synaptic clustering synchronicity and background activation (Disperse_equal_sized.hoc, Disperse_equal_sized_tuft.hoc, Disperse_6_2.hoc) is used to validate a mathematical model that predicts firing rate for various synaptic stimuli (figures 5 & 6).

If you have any problems using the model, please feel free to contact me at poirazi@imbb.forth.gr.
Hope this is helpful! Good luck,

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