DCS2017 Tutorial: Hodgkin-Huxley and Morris-Lecar neuronal dynamics

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1 Neuron models

Use XPP to investigate the dynamics of neuronal models discussed in the lectures.

Here is an .ode file for the Hodgkin-Huxley model (due to Bard Ermentrout):

```
# Morris-Lecar model Methods Chapter

# initial data
v(0)=-16
w(0)=0.014915
# functions
minf(v)=.5*(1+tanh((v-va)/vb))
winf(v)=.5*(1+tanh((v-vc)/vd))
tauw(v)=1/cosh((v-vc)/(2*vd))

dv/dt=(I0 - gca*minf(V)*(V-Vca)-gk*w*(V-VK)-gl*(V-Vl))/c
dw/dt=phi*(winf(V)-w)/tauw(V)



# parameters
param i0=0,vk=-84,vl=-60,vca=120
param gk=8,gl=2,c=20
param va=-1.2,vb=18
param vc=2,vd=30,phi=.04,gca=4.4
# parameter sets for different variants of the model
set snic {vc=12,vd=17.4,phi=.06666667,gca=4}
set hopf {vc=2,vd=30,phi=.04,gca=4.4}
```

```
set homo {vc=12,vd=17.4,phi=.23,gca=4}
# some numerical settings
@ total=150,dt=.25,xlo=-75,xhi=75,ylo=-.25,yhi=.5,xp=v,yp=w
done
}
```

and here is an .ode file for the Morris-Lecar model (also due to BE):

```
# Morris-Lecar model Methods Chapter

# initial data
v(0)=-16
w(0)=0.014915
# functions
minf(v)=.5*(1+tanh((v-va)/vb))
winf(v)=.5*(1+tanh((v-vc)/vd))
tauw(v)=1/cosh((v-vc)/(2*vd))

dv/dt=(I0 - gca*minf(V)*(V-Vca)-gk*w*(V-VK)-gl*(V-Vl))/c
dw/dt=phi*(winf(V)-w)/tauw(V)


# parameters
param i0=0,vk=-84,vl=-60,vca=120
param gk=8,gl=2,c=20
param va=-1.2,vb=18
param vc=2,vd=30,phi=.04,gca=4.4
# parameter sets for different variants of the model
set snic {vc=12,vd=17.4,phi=.06666667,gca=4}
set hopf {vc=2,vd=30,phi=.04,gca=4.4}
set homo {vc=12,vd=17.4,phi=.23,gca=4}
# some numerical settings
@ total=150,dt=.25,xlo=-75,xhi=75,ylo=-.25,yhi=.5,xp=v,yp=w
done
```

Notice that the different variants of the M-L models can be selected from within XPP.

2 Type I and type II dynamics

There are several differences between so-called type I and type II neurons that are now understood as a result of the different dynamics in the two cases.

Compute the bifurcation diagrams for the models above. In particular, show the following behaviours in your simulations (Ermentrout and Terman, 2010):

- Type I: Axons have sharp thresholds, can have long latency to firing, and can fire at arbitrarily low frequencies.
- Type II: Axons have variable thresholds, short latency, and a positive minimal frequency.

Hint: Pick the set ”snic” in M-L for type I behaviour, and set ”hopf” for type II behaviour.