This paper describes objective technical results and analysis. Any subjective views or opinions that might be expressed in the paper do not necessarily represent the views of the U.S. Department of Energy or the United States Government.

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Example Hodgkin-Huxley Cable

- $metadata
- $p = $t<100ms
- $t' = 0.01ms
- **C**
  - $inherit = "Coupling"
  - $metadata
    - $p = A.$index==B.$index-1
    - A = HH
    - A.I =+ -I
    - B = HH
    - B.I =+ I
    - G =: 2/(A.R+B.R)
    - I =: G*(A.V-B.V)
- **HH**
  - $inherit = "Cell Hodgkin-Huxley"
  - $metadata
  - $n = 3
  - $xyz = [($index+1)*length;0;0]
  - C = Cspecific*surfaceArea
  - Cspecific = 1(uF/cm2)
  - I =+ 20(uA/cm2)*surfaceArea @ $index==0
  - R = ρ*length/(π*r^2)
  - V = 0 @ $init
  - V' = I/C @ C
  - Vspike = 30mV
  - diameter = 1mm
  - diameter0 = diameter
  - fire =: V>Vspike
  - length =: 10mm
  - r =: (diameter+diameter0)/4
  - spike = fire
  - surfaceArea =:
    - ← 2*π*r*length
    - ← 4*π*r^2 @ length==0
  - x0 = output(V)
  - xyz0 =: [$index*length;0;0]
  - ρ = 30(Ohm.cm)
  - **K**
    - $inherit = "Channel K"
    - $metadata
    - $up.I =+ I
    - E = -77mV
    - G =: Gall*fopen*Q10Scaling
    - G1 = 0pS
    - Gall =: Gdensity*surfaceArea
    - Gdensity = 36(mS/cm2)
    - I =: G*(E-V)
    - Q10Scaling =*
    - fopen =*
    - population = 1
    - **n**
      - $inherit = "Gate"
      - $metadata
      - $up.fopen =* q^instances
      - Q10Scaling =*
      - inf =: α/(α+β) @ α+β
      - instances = 4
      - q = inf @ q==0
      - q' = (inf-q)/τ @ τ
      - α =: forwardRate.x
      - β =: reverseRate.x
      - τ =: τUnscaled/Q10Scaling
      - τUnscaled =: 1/(α+β)
    - **forwardRate (HHVariable Exponential Linear)**
    - **reverseRate**
      - $inherit = "HHVariable Exponential"
      - $metadata
      - a =: (V-midpoint)/scale
      - midpoint = -65mV
      - rate = 0.125kHz
      - scale = -80mV
      - x =: rate*exp(a,"median=1")
- **Na (Channel Na)**
- **leak (Channel Passive)**

Cable Model
has
has
Hodgkin-Huxley Coupling
connects
Hodgkin-Huxley Compartment
has
Ion Channel
has
Ion Gate
has
HH Variable

Coupling

- $metadata
- A = connect("Compartment")
- A.I =+ -I
- B = connect("Compartment")
- B.I =+ I
- G =: 2/(A.R+B.R)
- I =: G*(A.V-B.V)

Compartment

- $inherit = "Spike Source"
- $metadata
- C = 100pF
- I =+
- V = 0 @ $init
- V' = I/C
- Vspike = 30mV
- fire =: V>Vspike
- spike = fire

Cell Hodgkin-Huxley

- $inherit = "Segment"
- $metadata
- **K**
  - $inherit = "Channel K"
- **Na**
  - $inherit = "Channel Na"
- **leak**
  - $inherit = "Channel Passive"

Segment

- $inherit = "Compartment"
- $metadata
- $xyz = [0;0;0]
- C = Cspecific*surfaceArea
- Cspecific = 1(uF/cm2)
- R = ρ*length/(π*r^2)
- V' = I/C @ C
- diameter = 1um
- diameter0 = diameter
- length =: norm($xyz-xyz0,2)
- r =: (diameter+diameter0)/4
- surfaceArea =: ←
- xyz0 =: $xyz
- ρ = 30(Ohm.cm)

Channel K

- $inherit = "Channel"
- $metadata
- E = -77mV
- Gdensity = 36(mS/cm2)
- **n**
  - $inherit = "Gate"
  - instances = 4
  - α =: forwardRate.x
  - β =: reverseRate.x
- **forwardRate**
  - $inherit = "HHVariable Exponential Linear"
  - midpoint = -55mV
  - rate = 0.1kHz
  - scale = 10mV
- **reverseRate**
  - $inherit = "HHVariable Exponential"
  - midpoint = -65mV
  - rate = 0.125kHz
  - scale = -80mV

Channel

- $metadata
- $up.I =+ I
- E = 0mV
- G =: Gall*fopen*Q10Scaling
- G1 = 0pS
- Gall =: Gdensity*surfaceArea
- Gdensity = 0(mS/cm2)
- I =: G*(E-V)
- Q10Scaling =*
- fopen =*
- population = 1

Gate

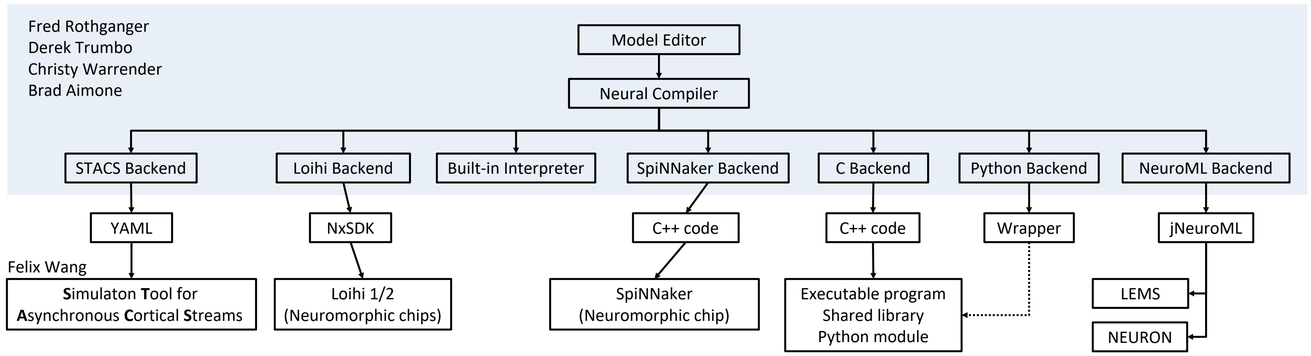
- $metadata
- $up.fopen =* q^instances
- Q10Scaling =*
- inf =: α/(α+β) @ α+β
- instances = 1
- q = inf @ q==0
- q' = (inf-q)/τ @ τ
- α =: 0Hz
- β =: 0Hz
- τ =: τUnscaled/Q10Scaling
- τUnscaled =: 1/(α+β)

HHVariable

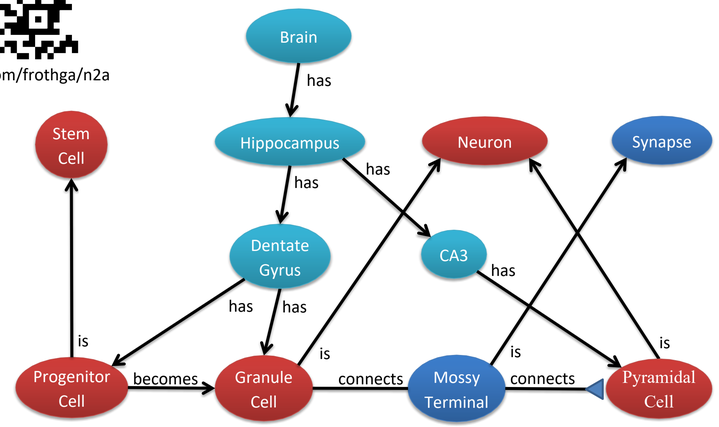
- $metadata
- a =: (V-midpoint)/scale
- midpoint = 0mV
- rate = 0
- scale = 100mV
- x =: rate

HHVariable Exponential

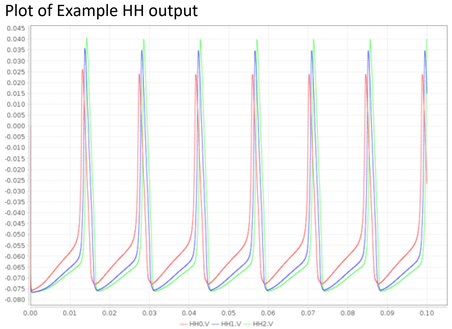
- $inherit = "HHVariable"
- $metadata
- x =: rate*exp(a,"median=1")



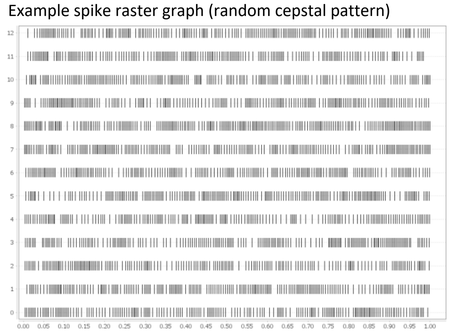
https://github.com/frothga/n2a



Plot of Example HH output



Example spike raster graph (random cepstal pattern)



Summary

- ❑ Object oriented
  - Models may inherit from and extend other models
  - Models may contain other models as subparts
- ❑ Models are data, not code (Declarative, not imperative)
  - Allows models to override other models at the attribute level
  - No limit to scaling or degree of recombination
  - Enables high-level analysis, such as algorithm extraction (future work)
- ❑ Define your own parts
  - Example library provided, including common neuron and synapse models
- ❑ Model at your preferred level of abstraction
  - Most physical processes can be expressed as systems of ODEs

Recently completed

- Multiple repositories
- Share models via Git
- Graphical editor
- Parameter space exploration
- Remote job control via ssh

Ongoing work

- Parallel execution in C and Internal backends
- NEST backend
- Python module from generated C++ code
- Remote jobs via Neuroscience Gateway (NSG)

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