Simulation and Visualization of Custom Neuromorphic Hardware using NeMo

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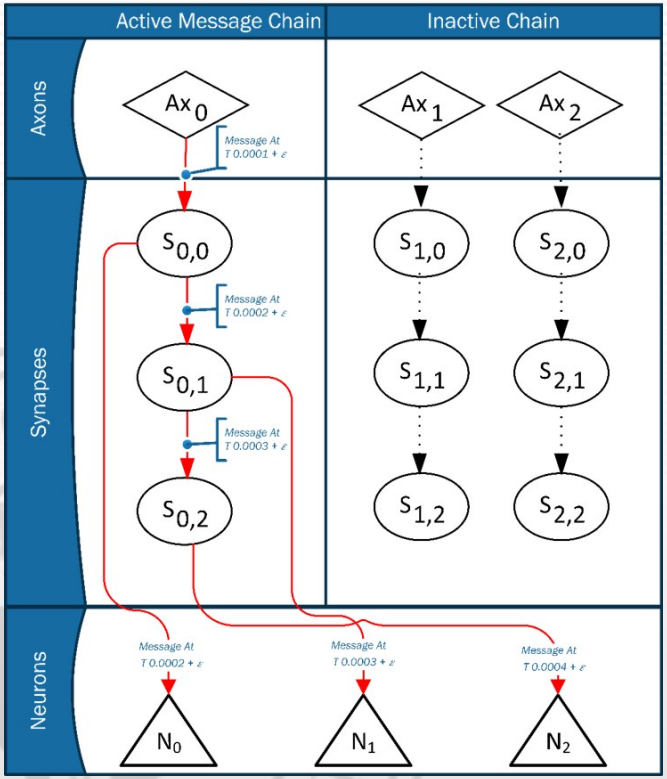
Rensselaer

NeMo:

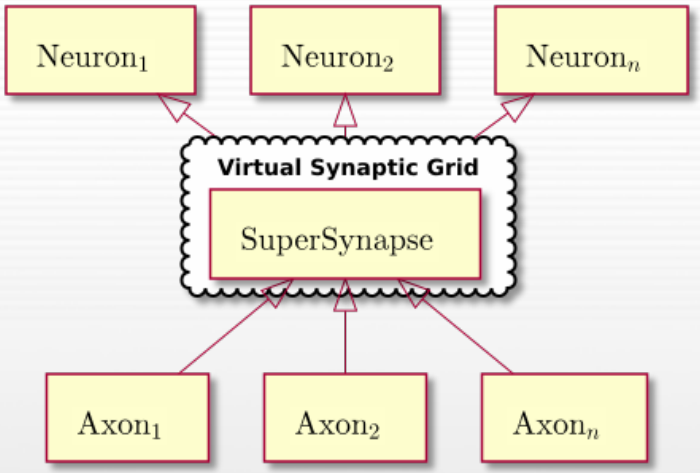
- Uses Parallel Discrete Event Simulation (PDES)
- Built on top of ROSS (Rensselaer Optimistic Simulation System)
- Able to simulate existing and novel neuromorphic hardware models
- Validated against TrueNorth

NeMo and NeMo 2

NeMo 1



NeMo 2



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IO Details

- Embedded Lua interpreter
- Network configuration files are valid Lua source
  - Allows very flexible and expressive configuration
  - Potential dynamic behaviors
  - Fine grained error checking

IO Details

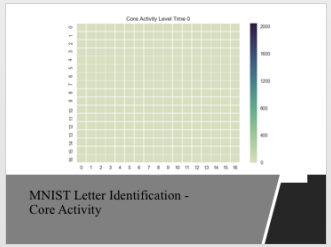
- Embedded Lua interpreter

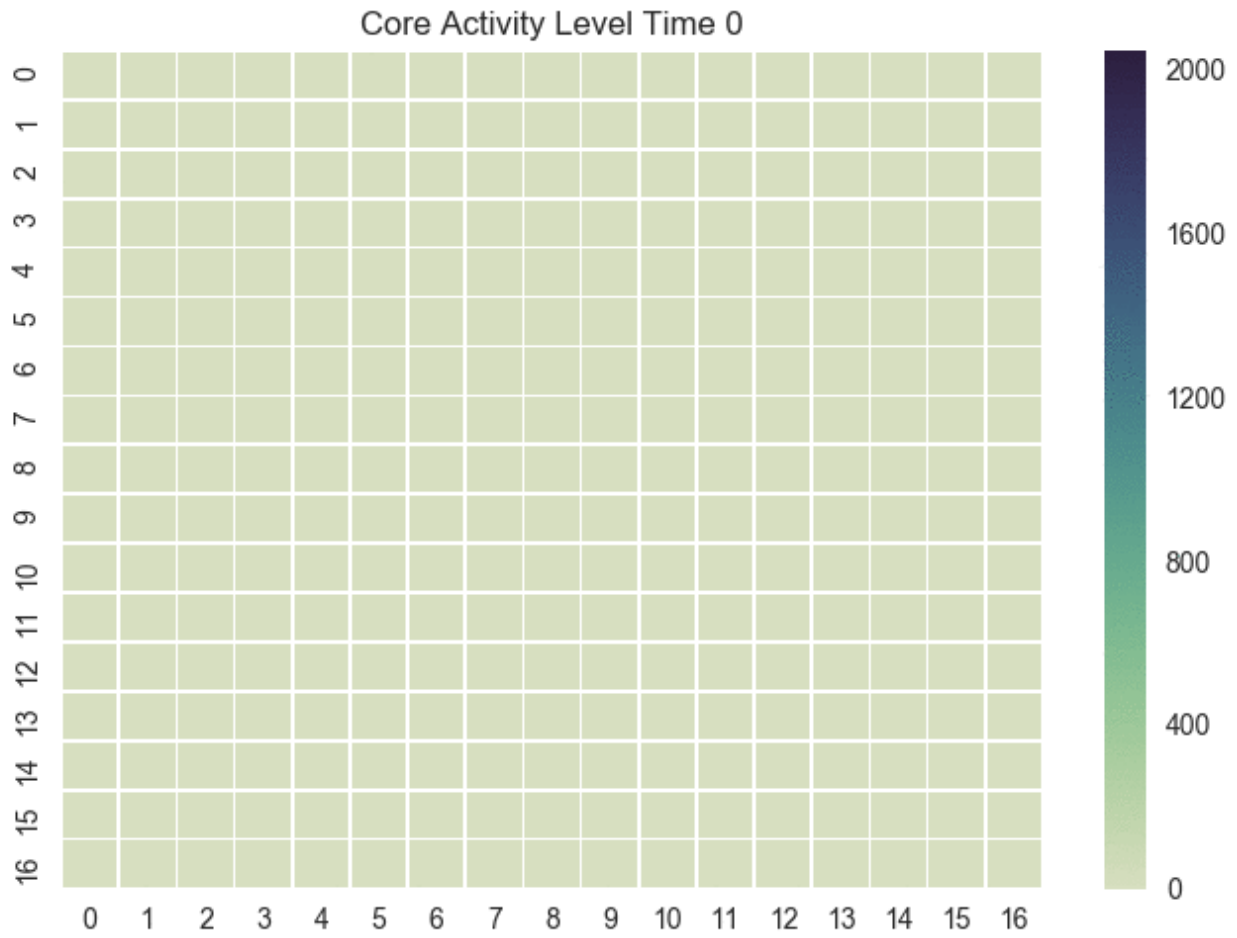
```
--NeMo Configuration-
cores = 256
neuronsPerCore = 256
neuronWeights = 4

--Neuron Definitions-
neurons = { TN_2_0 = {type = “TN”, coreID=2, localID =0, alpha=1, beta=2,...},
TN_2_1 = {type = “TN”, coreID=2, localID =1, alpha=3, beta=0,...},
TN_2_2 = {type = “TN”, coreID=2, localID =2, alpha=4, beta=0,...},
TN_2_3 = {type = “TN”, coreID=2, localID =3, alpha=4, beta=0,...}}
```

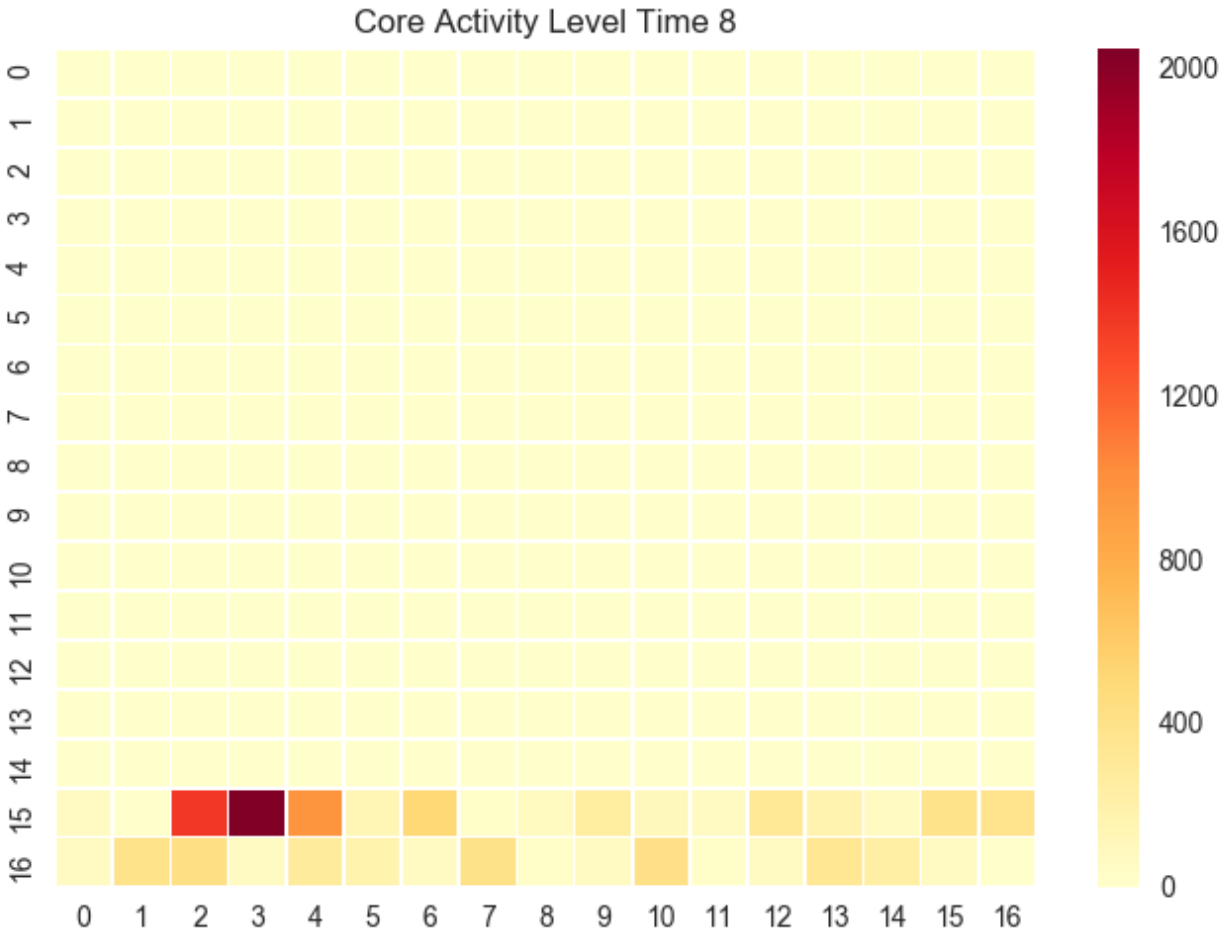
NeMo Instrumentation

- New ROSS / CODES feature
  - Low model overhead instrumentation
- Implemented in NeMo:
  - Event Tracing
  - Tracks Neuron Activity:
    - *Spikes & Integration Per Tick*
    - *Sent Messages*

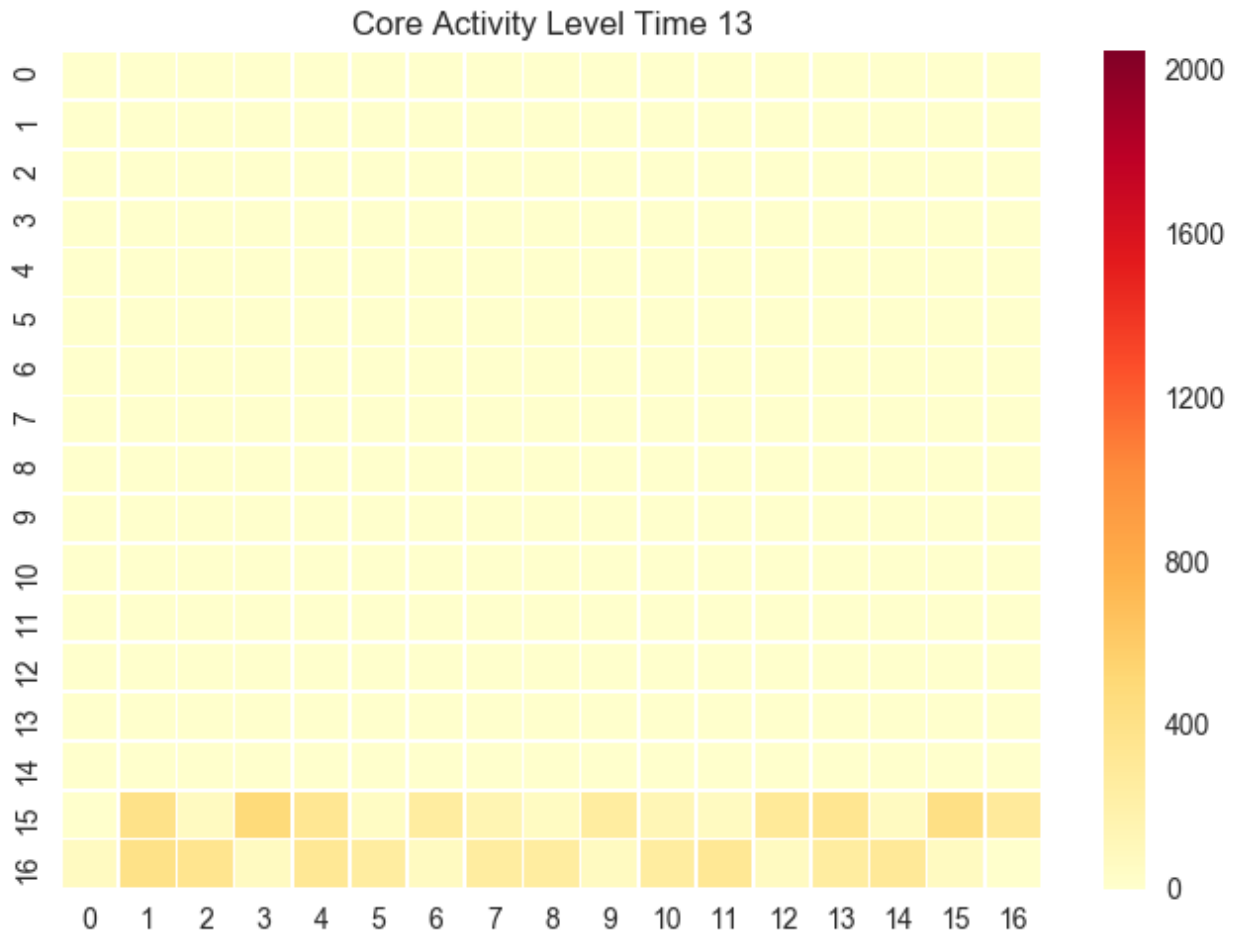




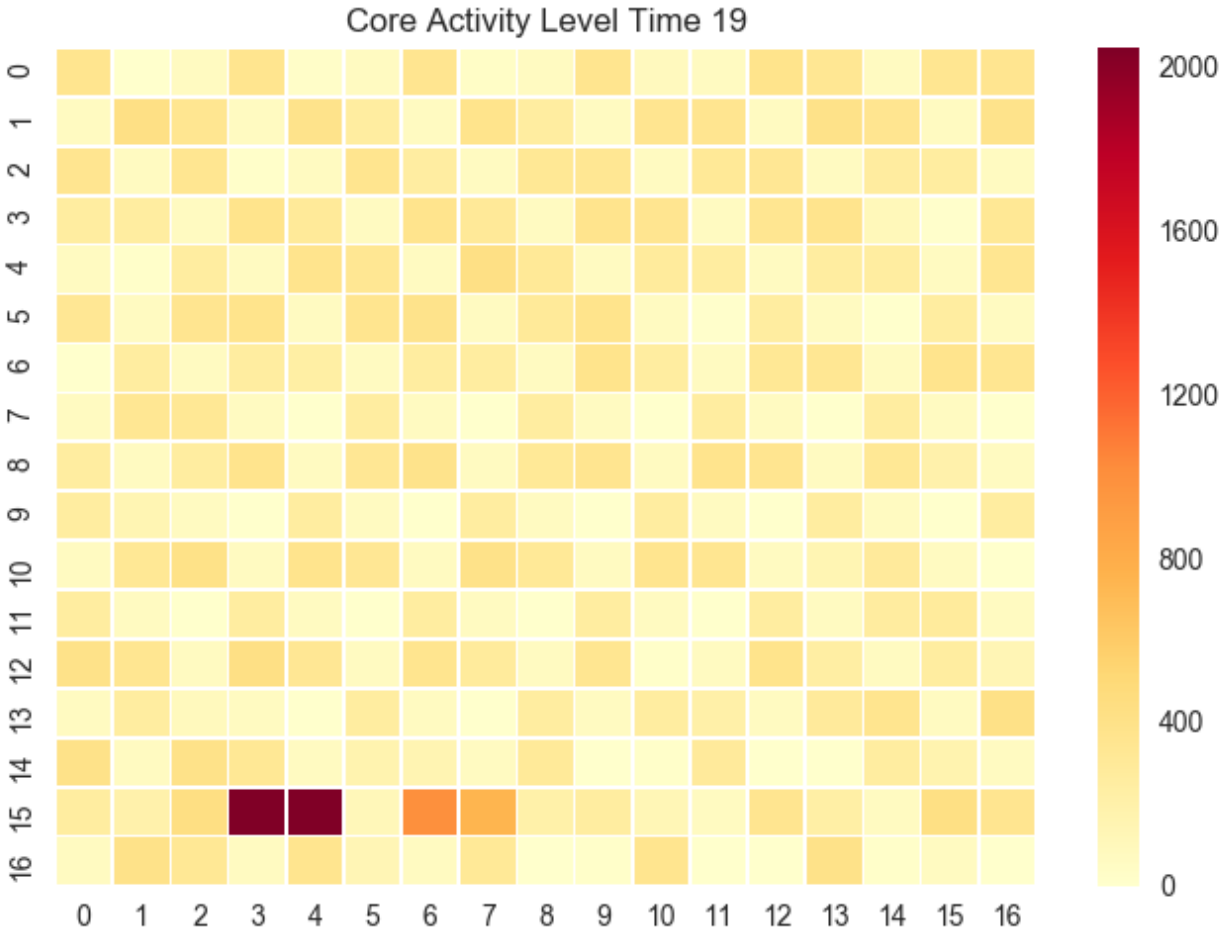
MNIST Letter Identification - Core Activity



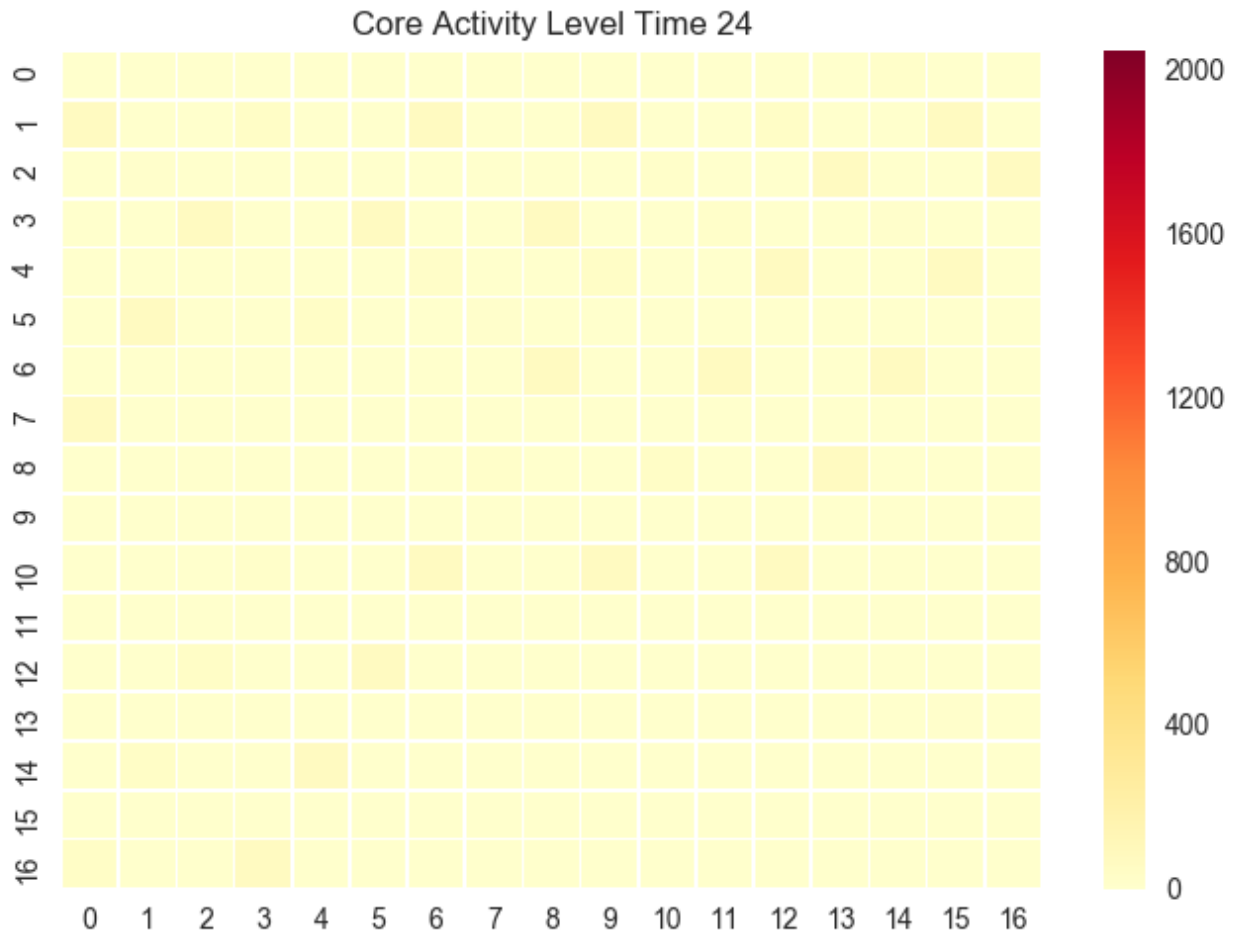
MNIST Letter Identification - Core Activity



MNIST Letter Identification - Core Activity



MNIST Letter Identification - Core Activity



MNIST Letter Identification - Core Activity

Performance

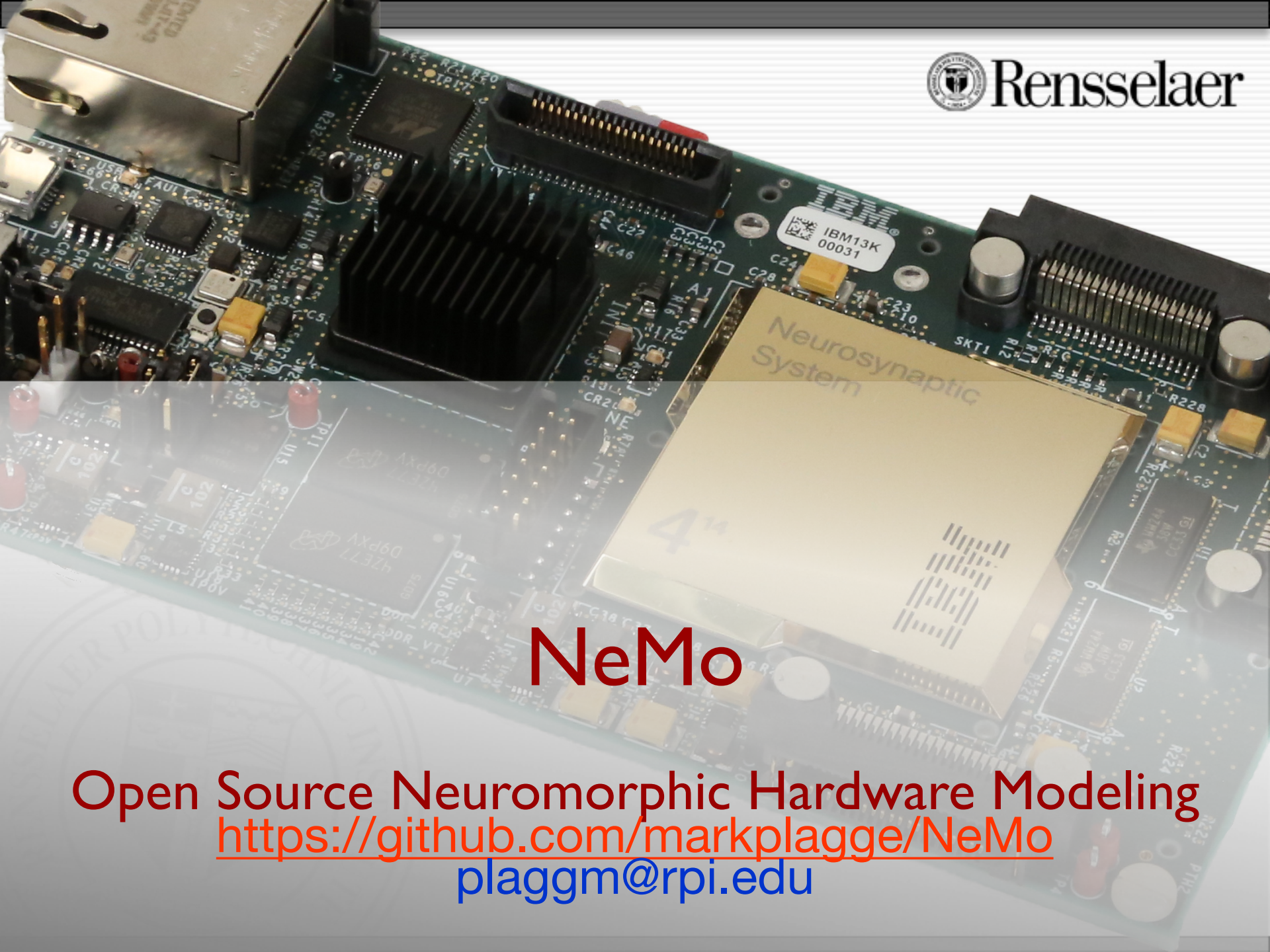
- Excellent performance when simulating large systems and smaller systems
- Able to simulate many types of hardware
- Small enough memory footprint to run simple models on desktop hardware

Instrumentation

- Adds ability to trace and debug models
- Currently provides way to view core activity over time
- Potential applications include
  - Power use estimates
  - Core-wise debugging

Future Work

- Integration with supercomputing simulation framework
- Further performance and usability improvements



NeMo

Open Source Neuromorphic Hardware Modeling

https://github.com/markplagge/NeMo

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Rensselaer

Appendix

Notes and Extras

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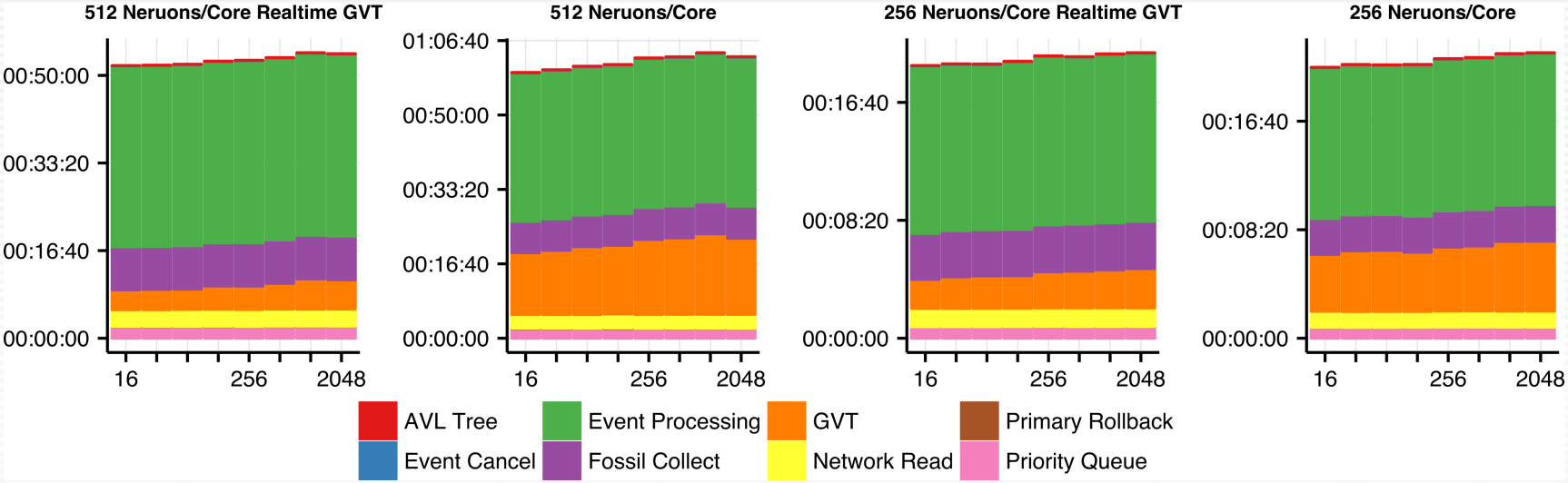
Rensselaer

Input File Def / Status

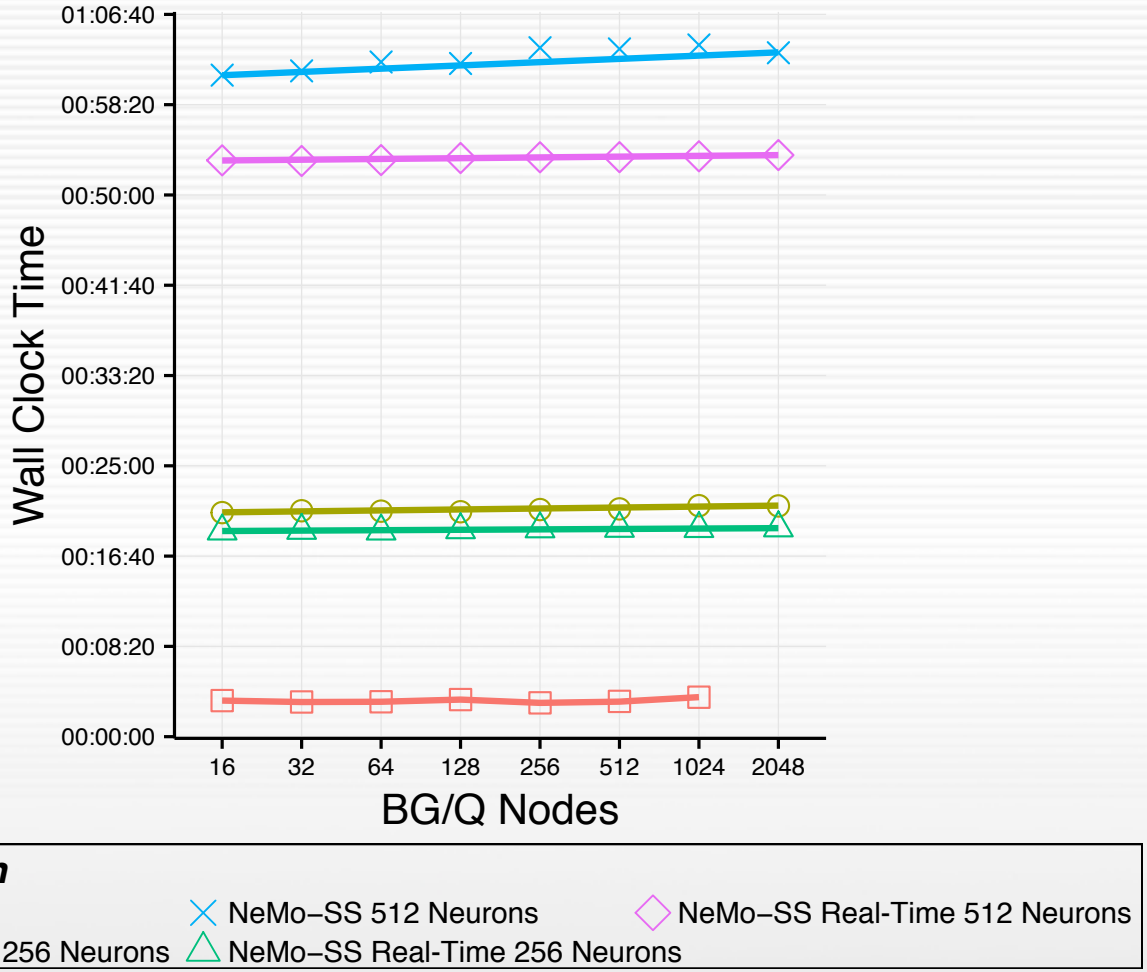
- Still WIP - Currently 2 Files:
- CSV for input spikes
  - (time, destCore, destAxon)
- Lua for network config
  - List of defined variables
  - Dictionary (key/value pair) per neuron
- Subject to change – Final def. will be uploaded to NeMo GitHub Wiki



Weak Scaling Wall-Clock Time

Performance Results

- Weak Scaling on the Blue Gene/Q
- Simulation ran for 1,000 Ticks
  - 1 second real-time



COMPASS Comparison

- COMPASS results were reported as neurosynaptic events per second
- NeMo's results were total events per second
  - Includes all axon, synapse, and neuron events
- To compare, we calculated equivalent COMPASS events per second

COMPASS Comparison

- For every neuron spike in NeMo-ES
  - 256 events generated with one axon event
- Assumed that COMPASS has 50/50 remote to local events

$$e_{total} = s_{reported} \times 2 \times f$$

$$e_{second} = \frac{e_{total}}{t}$$

$$e_{second/rack} = \frac{e_{second}}{16}$$

Validation

- Validated NeMo against two of Izhikevich's *Biologically Relevant Behaviors* as seen in Cassidy, et al. 2013