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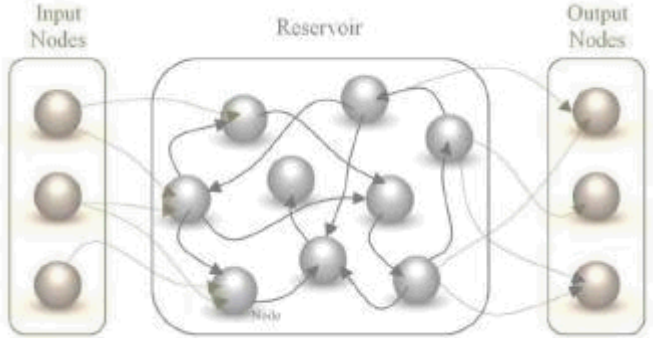

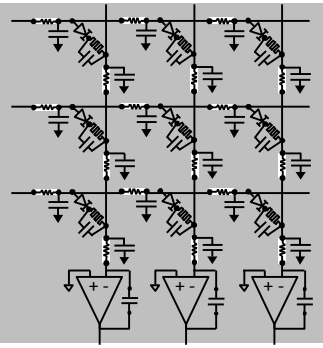

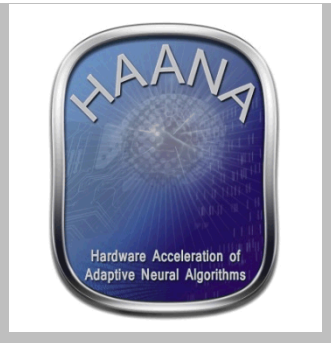

Liquid State Machine on Crossbar Device Modeling

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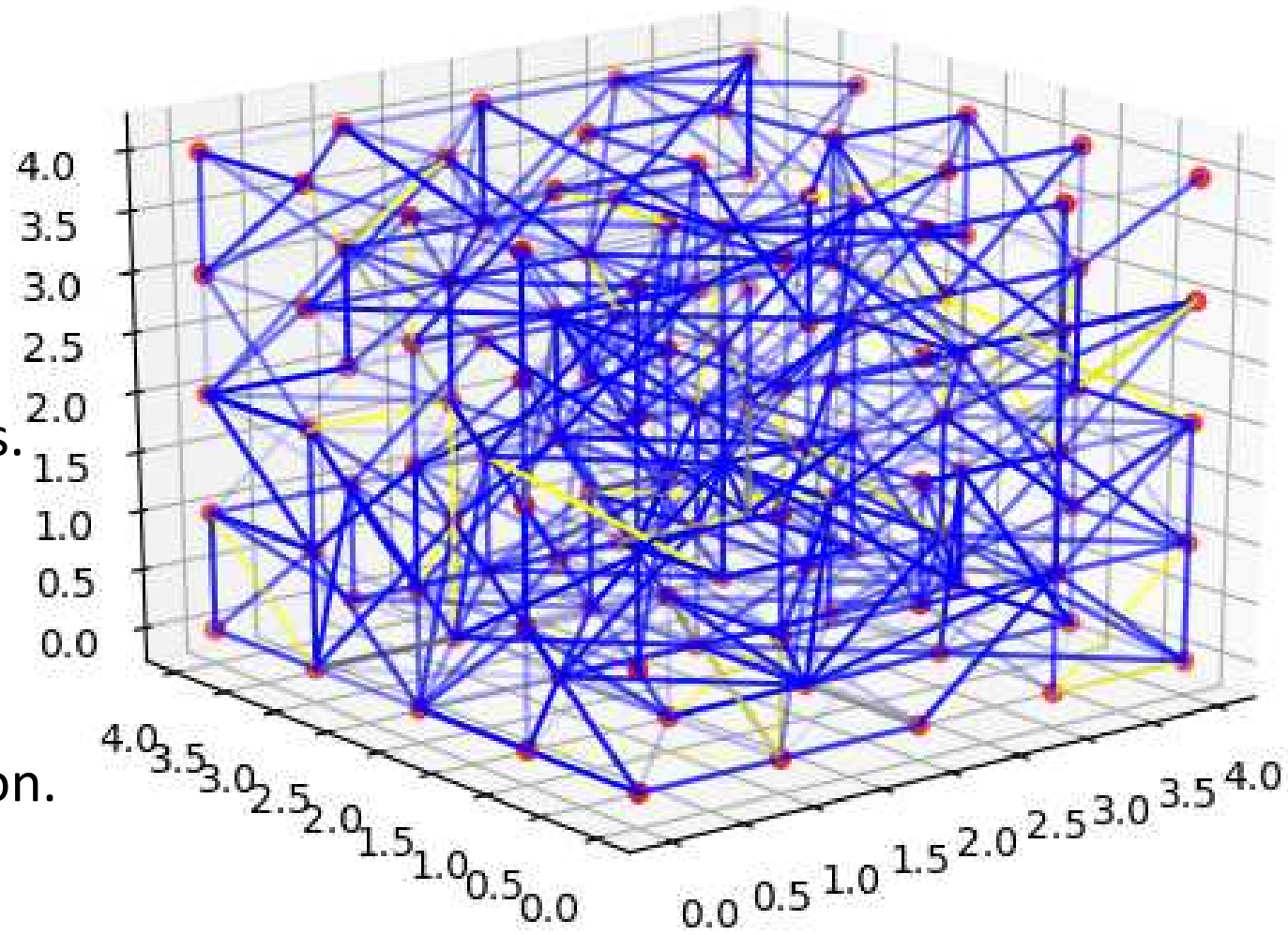
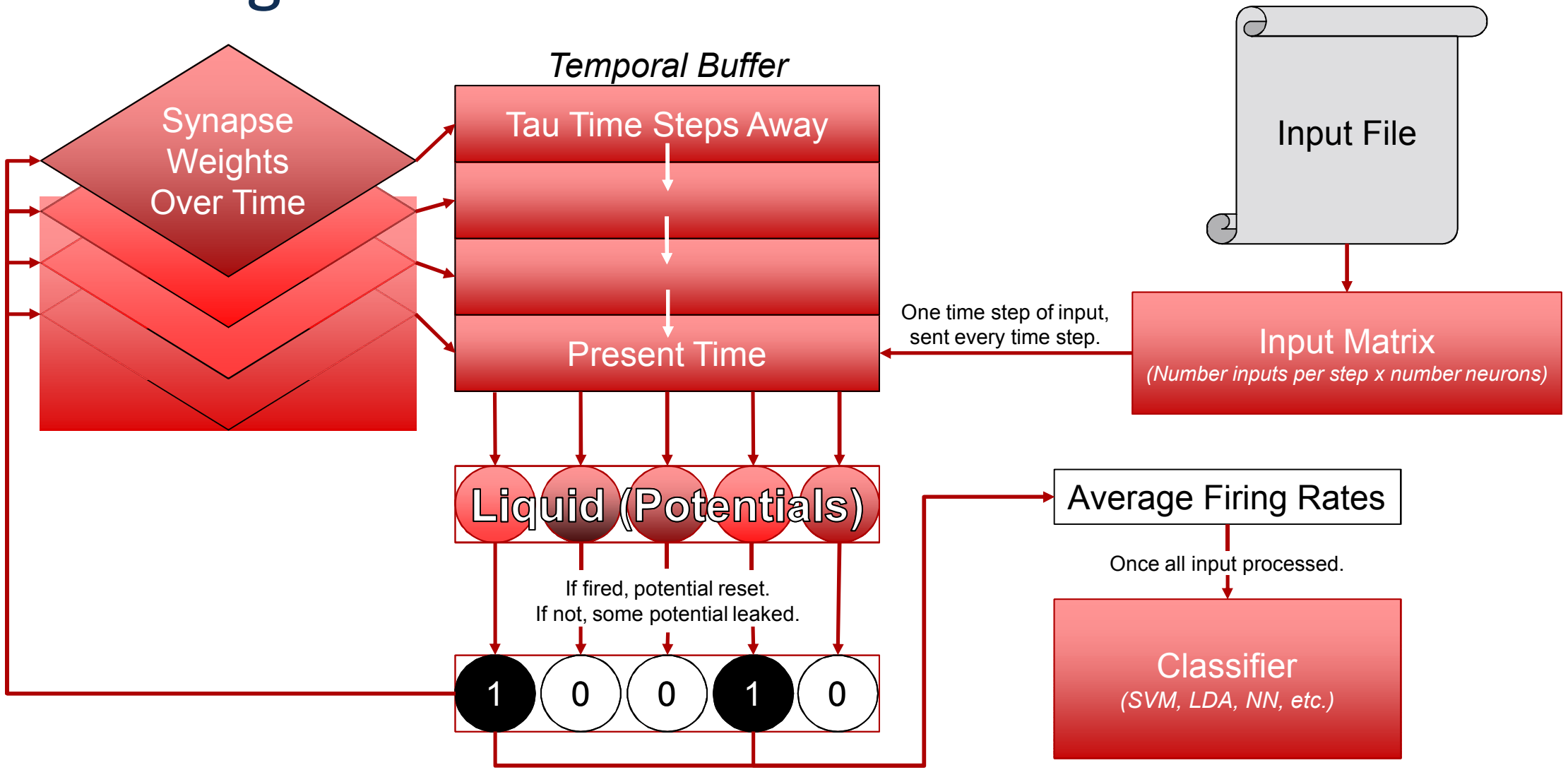
What is a Liquid State Machine (LSM)?

- Ripples on a liquid.
- Untrained reservoir.
- Expansion to higher dimensions.
- Multiple readouts.
- Temporal stack & direct injection.

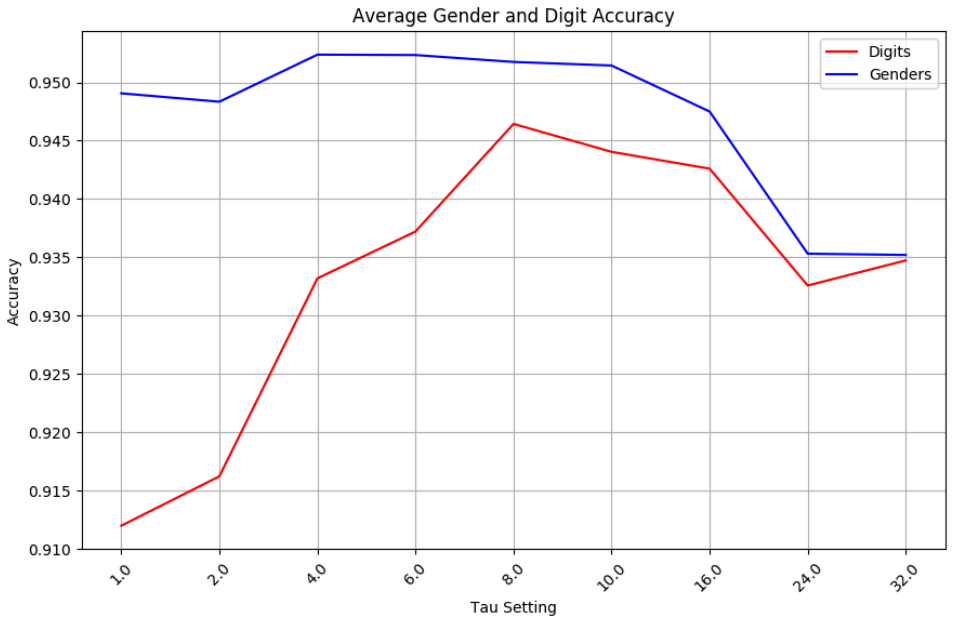


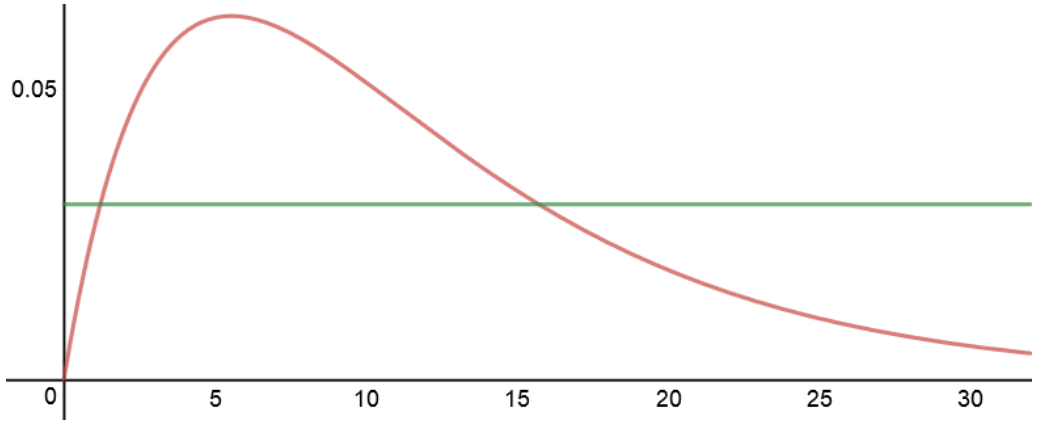
LSM Program Flow



Early Models and Tests

- Started with flat function.
- Neuron vs synapse mode.
- SVM vs LDA.
- Optimal tau settings.
- Overflow.
- Second order response function.





Cross-Sim and Error

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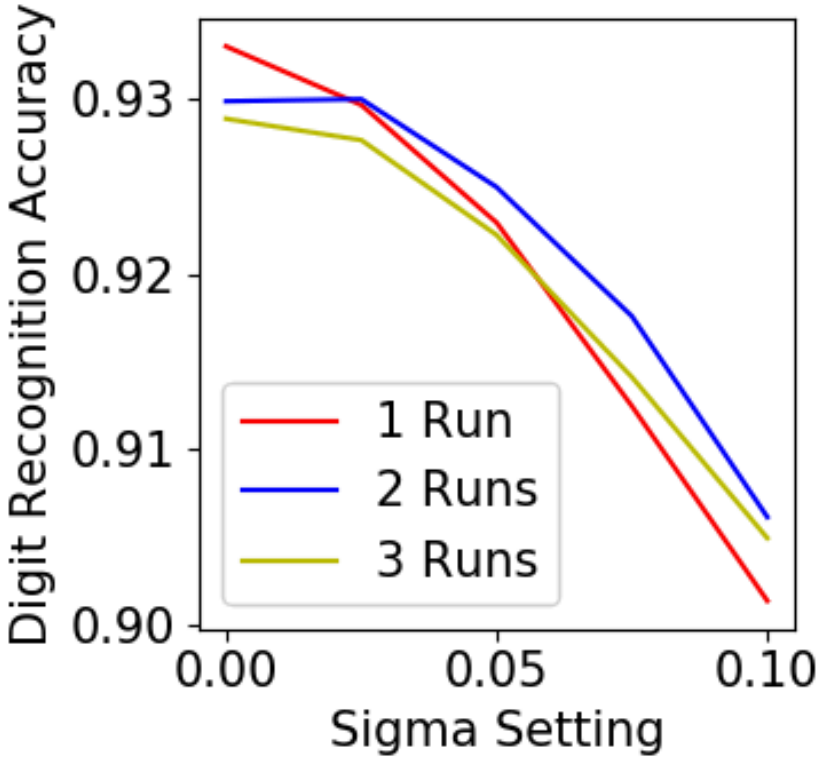
- Read noise and write noise.
- Gaussian noise distribution.
- Noise never helps, but can be resisted.
- Tried several noise resistance techniques.
  - Multiple runs.
  - Multiple crossbars.
  - Random response function.
  - Neural net classification.

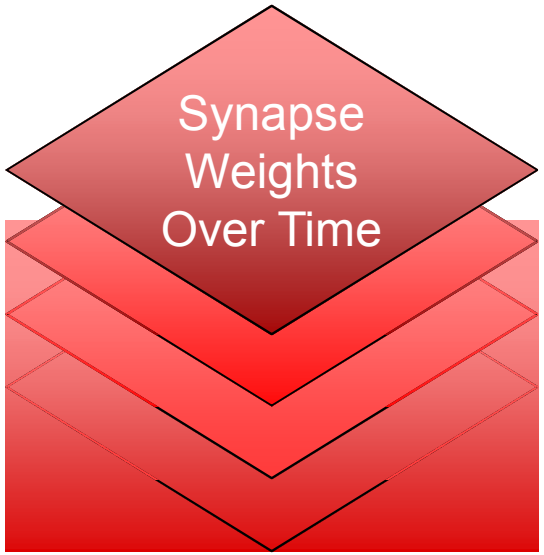
Multiple Runs

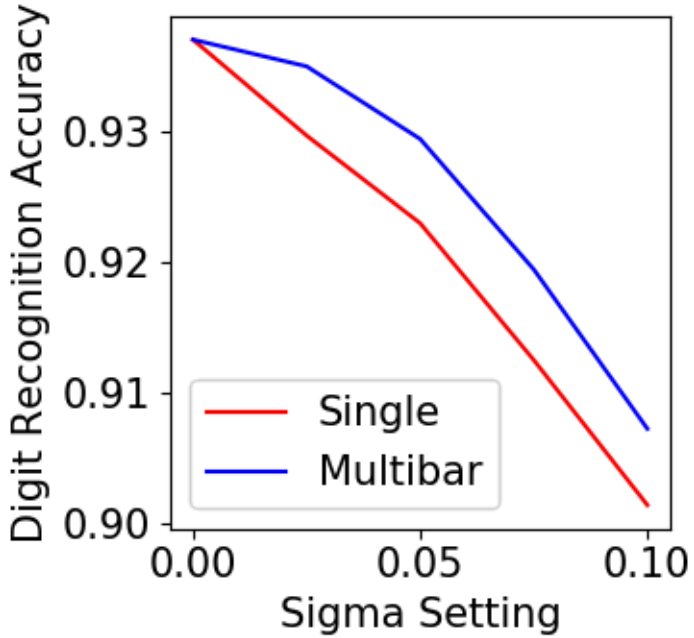
- Run data through liquid multiple times for multiple noisy readings.
- Helps accuracy slightly.
- Optimal amount of runs.
- May cause overfitting.



Multiple Crossbars

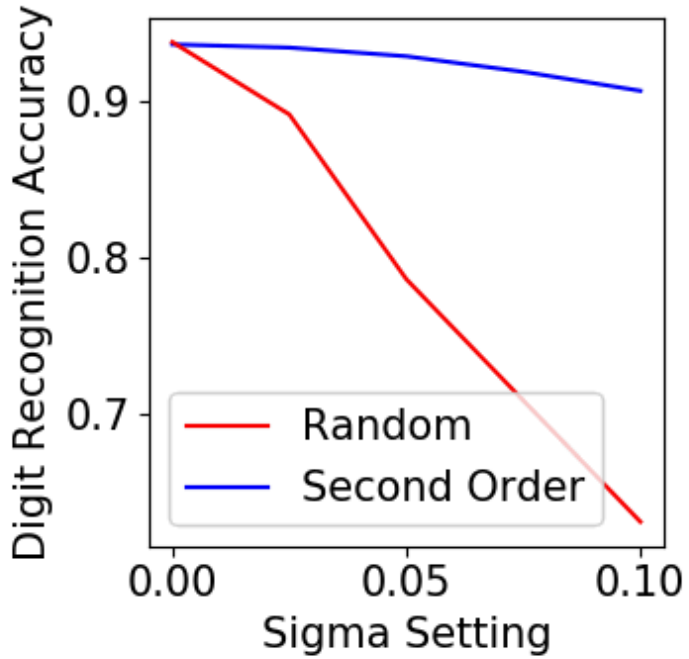
- Utilize multiple crossbars and scale weights to function during setup.
- Improves accuracy slightly.





Random Response Function

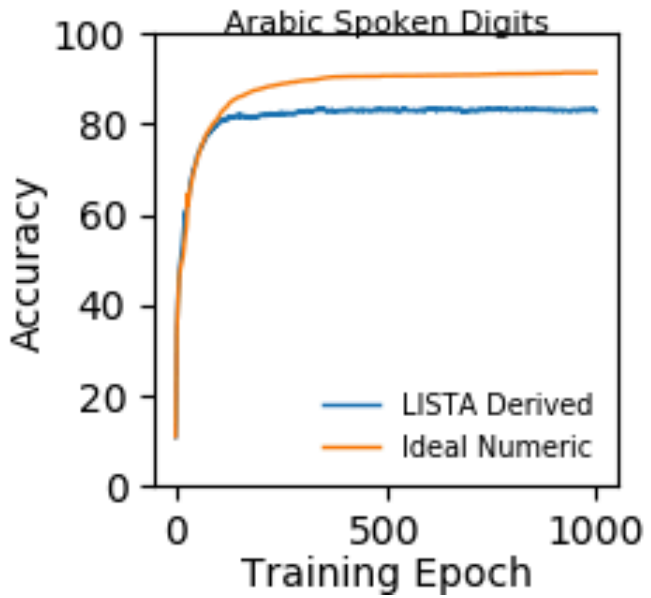
- Fully utilizes features of multiple crossbar setup.
- May be able to be improved.
- More testing required.

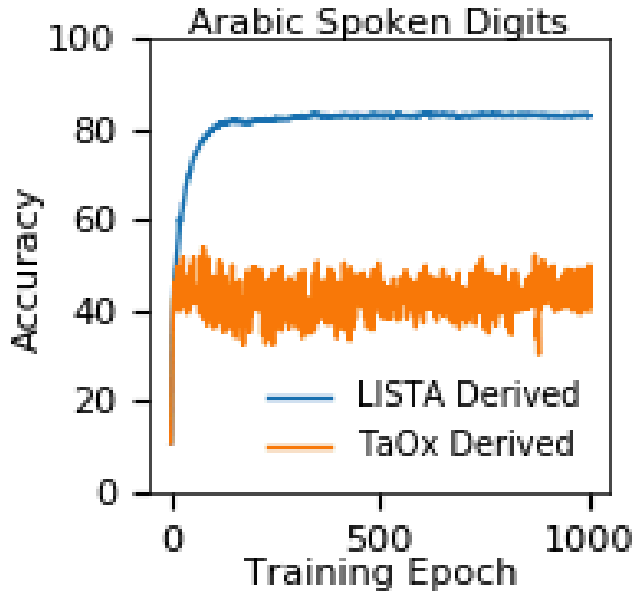


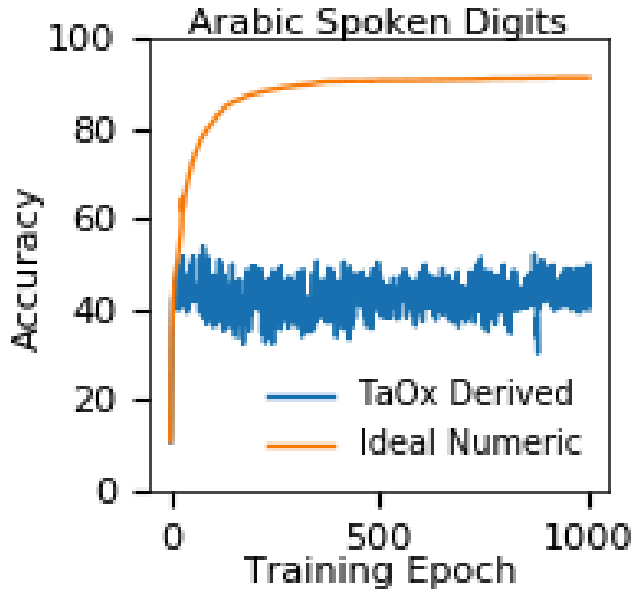
Neural Nets

- Conducted on 5% noise data.

- Peak accuracy of 91% with ideal parameters.







Summary

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- Peak accuracy of around 93-94% with second order function.
- LSM on Crossbar devices can retain 90% accuracy past 10% read noise.
- Various techniques can be combined to further increase accuracy.
- LSM is well suited to STPU architecture.

Future Work

- Possible means of training the liquid.
- Classifying based off of firing history.
- Optimizing SVM/LDA classification.
- Optimize parameters of net for each function.