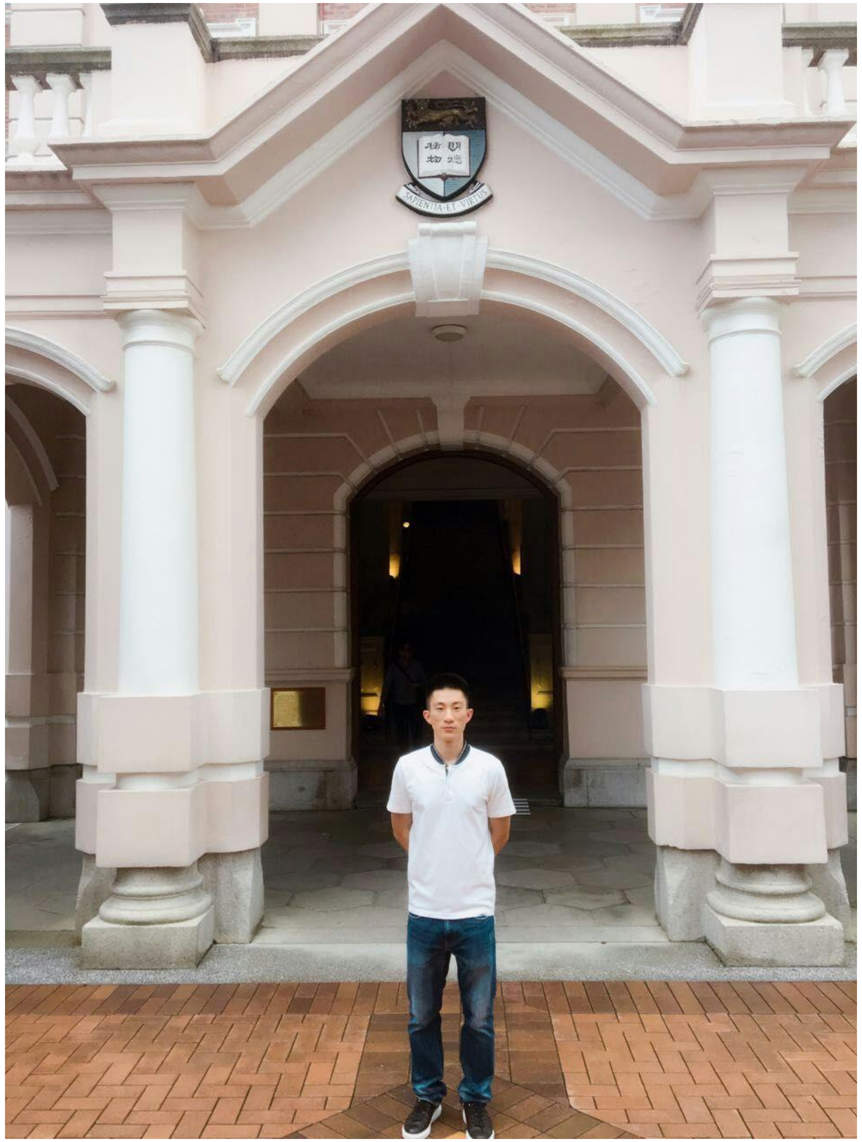
Hello! Everyone

I am the speaker of this paper, titled "A Memristor-Based Spiking Neural Network with High Scalability and Learning Efficiency"

Lianhua Qu



IEEE International Symposium on Circuits & Systems

Virtual, October 10-21 2020

# A Memristor-Based Spiking Neural Network with High Scalability and Learning Efficiency

Lianhua Qu
qulianhua14@nudt.edu.cn
2020-09-02

# 1. Introduction

## 1.1 The fundamentals of SNNs

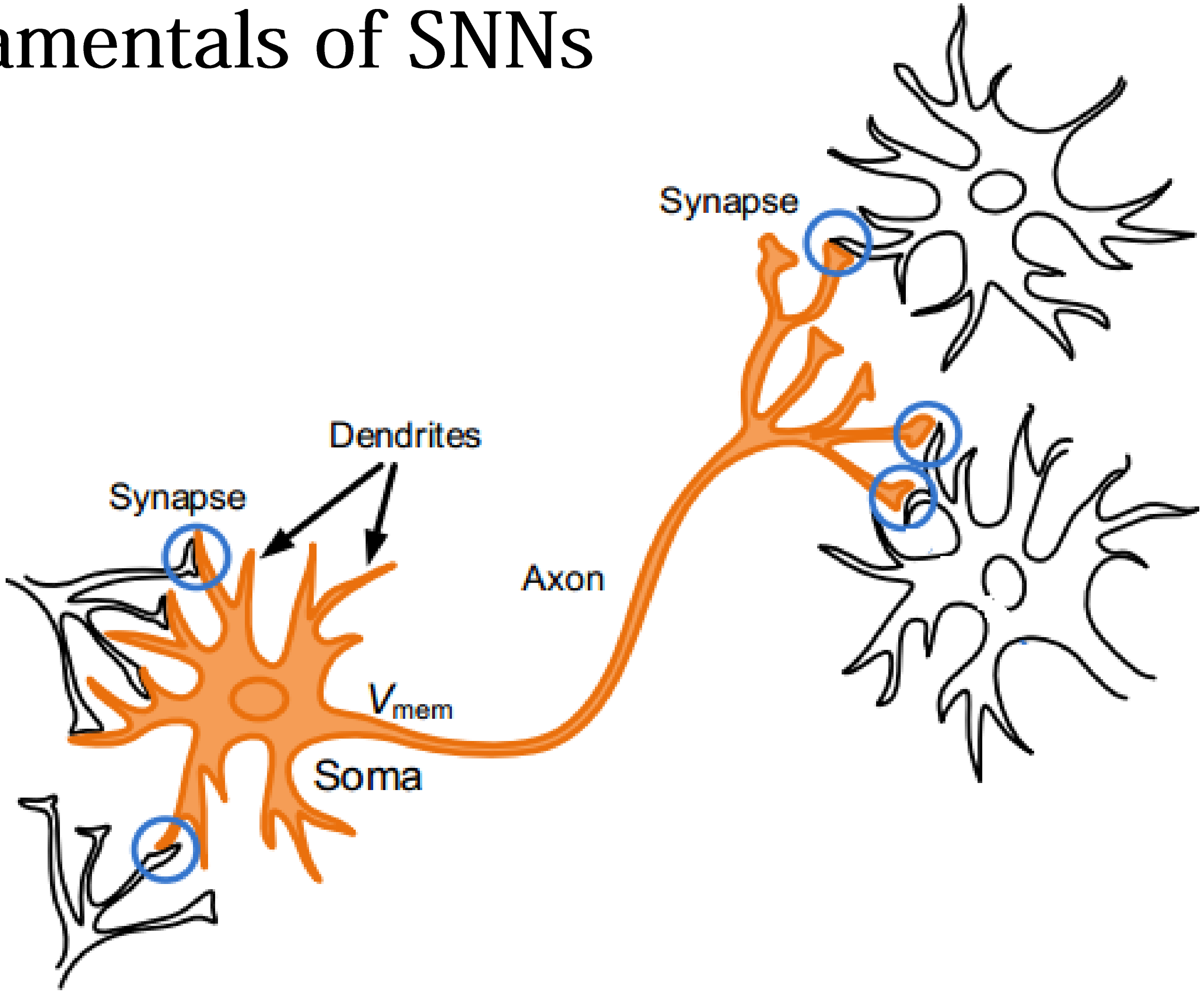



Fig 1. The schematic of biological neural system, mainly composed of spiking neuron, axon, dendrite, and synapse.

# 1. Introduction

## 1.1 The fundamentals of SNNs

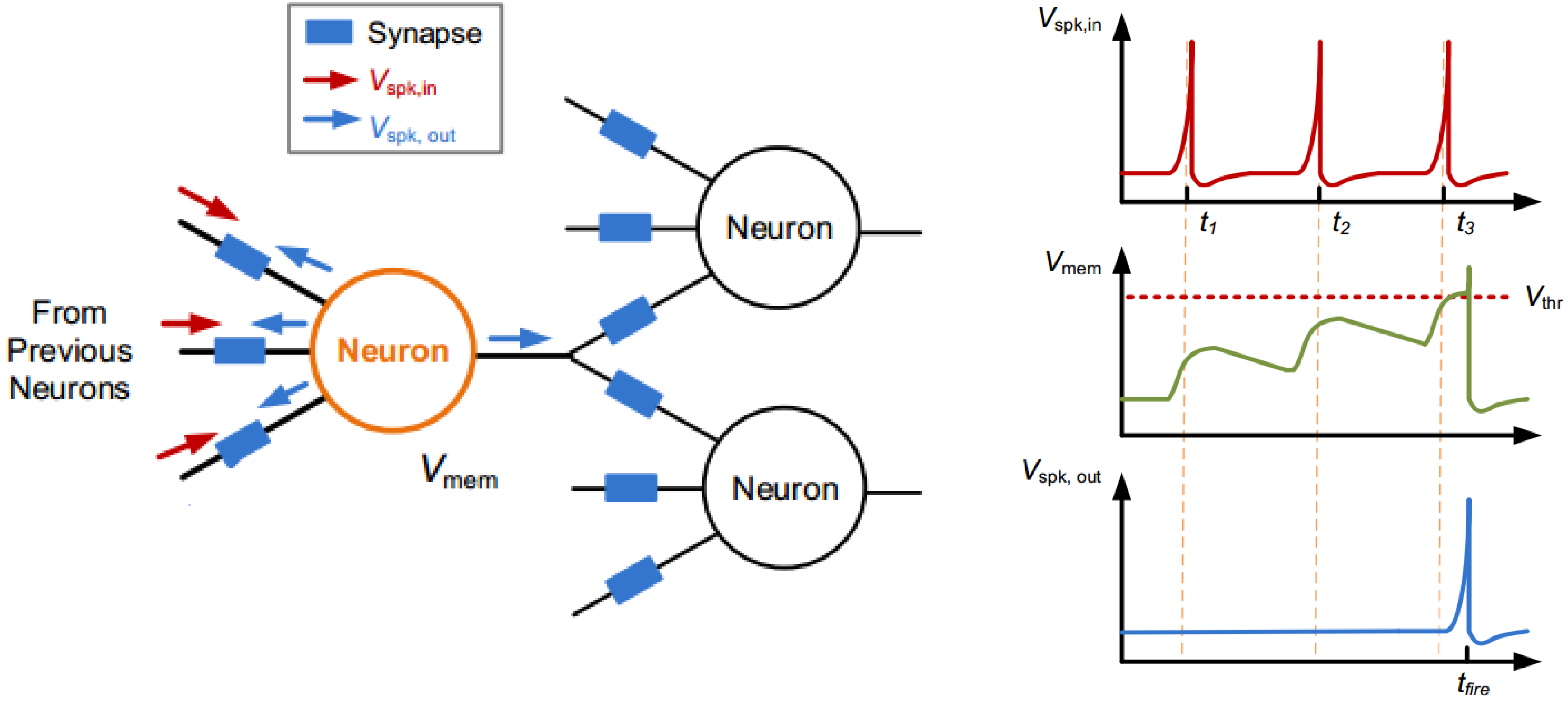



Fig 2. The spiking neual model abstracted from biological neural systems, and the working mechnism of a typical integrate and firing neruon.

# 1. Introduction

## 1.1 The fundamentals of SNNs

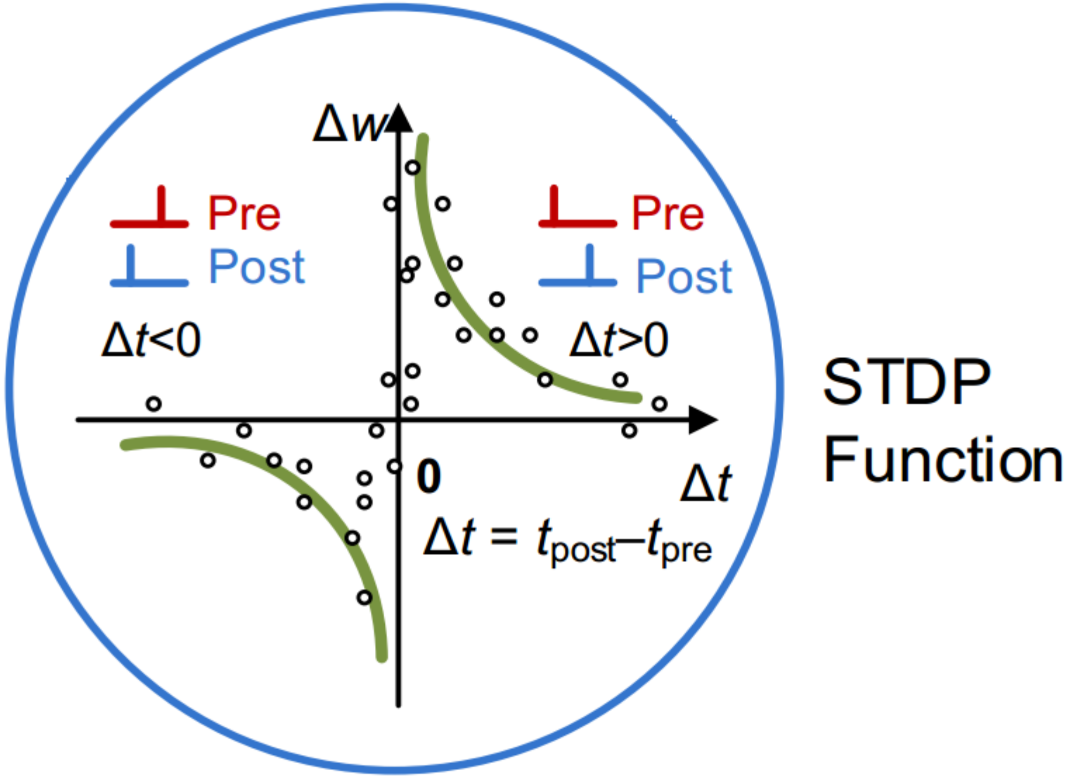



Fig. 3 Synpatic weight *w* can be modulated by the pre- and post-synpatic spikes, which is ploted as the STDP function.

With STDP, repeated pre-synaptic spike arrival before post-synaptic spike leads in a larger synaptic weight; whereas repeated spike arrival after postsynaptic spikes leads to a smaller synaptic weight.

# 1. Introduction

## 1.2 Two kinds of network architecture for STDP-based SNNs

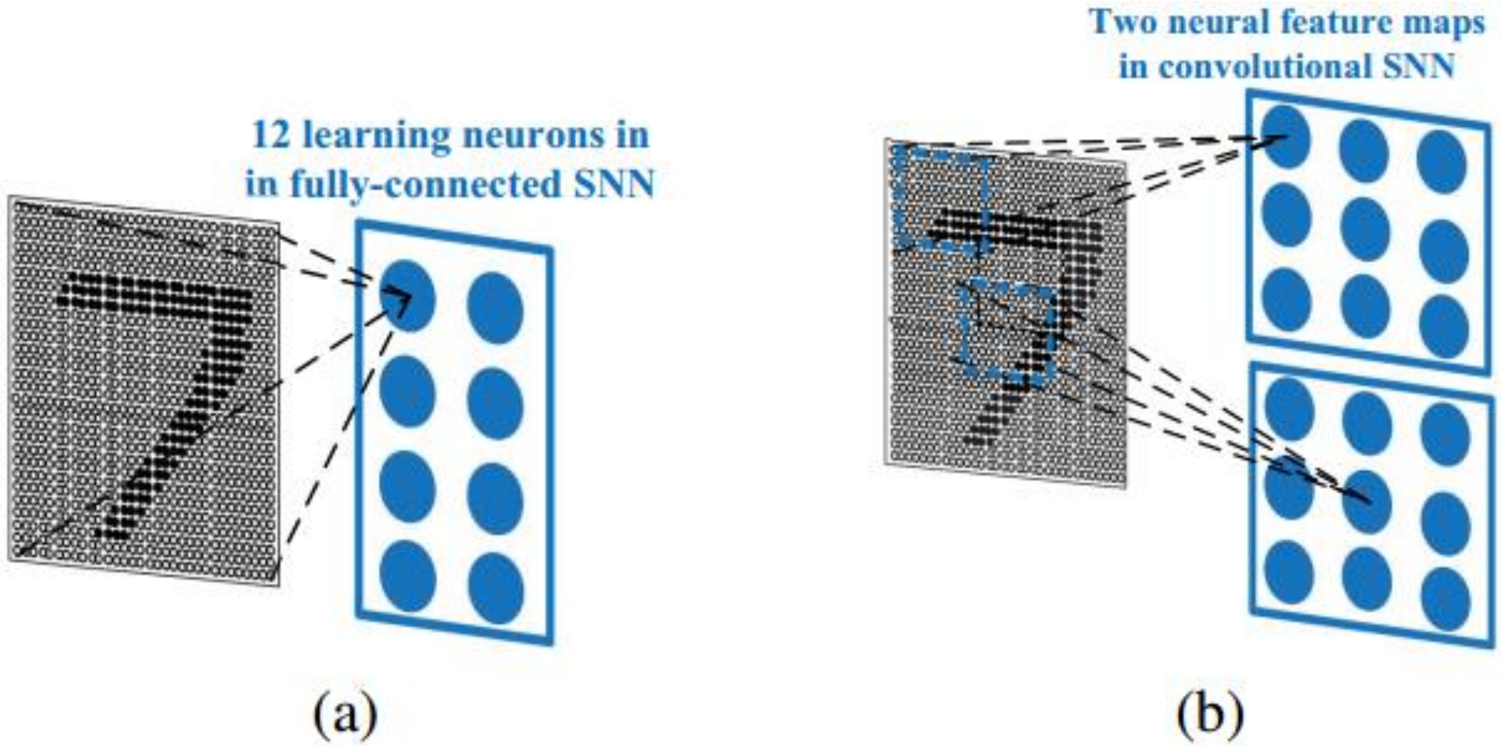



Fig. 4 The network architecture of one learning layer for fully-connected and convolutional architectures of SNN.

# 1. Introduction

## 1.3 Another two mechanisms demanded for STDP-based SNN

Lateral inhibition:

Lateral inhibition forces neurons (or different neural feature maps) in the same layer to learn different patterns by preventing other neurons from firing when one neuron has already responded to the input pattern .

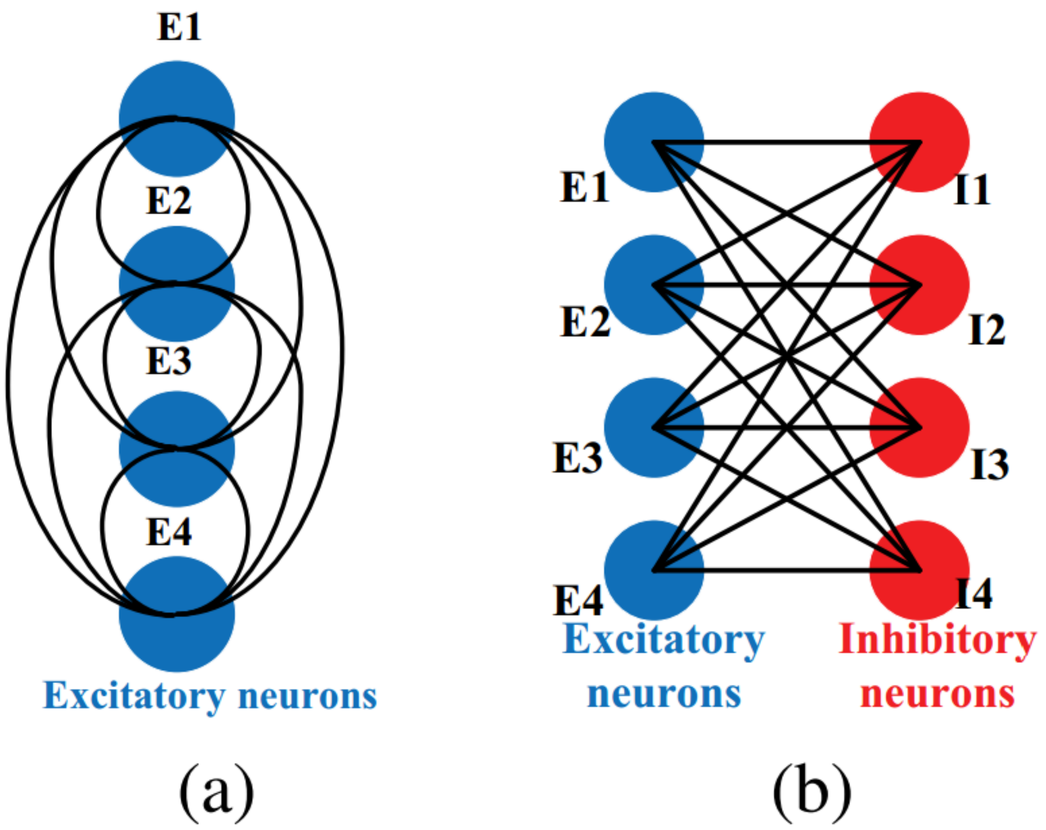



Fig. 5 The network topology of two lateral inhibition methods that are widely used in software simulations.

# 1. Introduction

## 1.3 Another two mechanisms demanded for STDP-based SNN

Homeostasis method:

Homeostasis method is used to reduce inhomogeneity, depressing the neuron with high firing frequency and potentiating the neuron with low firing frequency, to make sure that every neuron in the same layer has the same opportunity to fire and learn

国防科技大学 National university of defense technology

## 1.4 Memristor-based synapse

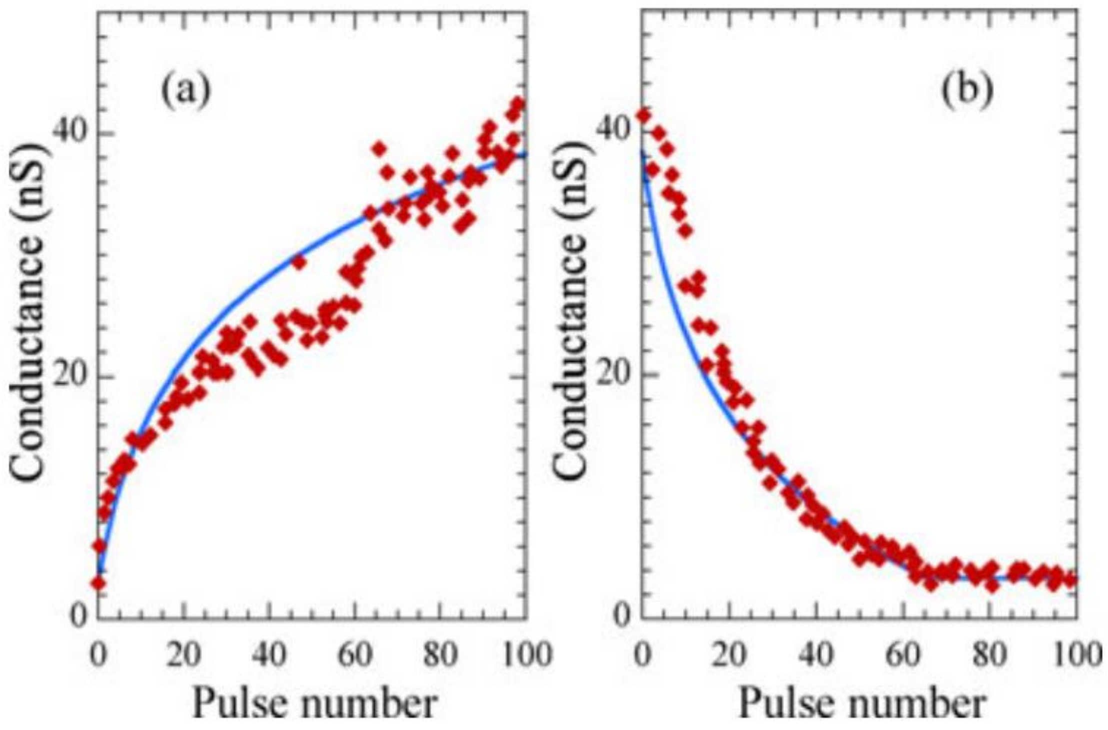



Fig. 6 The biological plausible STDP rules shown in experiments on memristor. The device conductance of memristor after positive voltage pulses (a) and after negative voltage pulses (b).

# 2. Methods

## 2.1 The proposed method to realize homeostasis and lateral inhibition for fully-connected and convolutional SNNs.

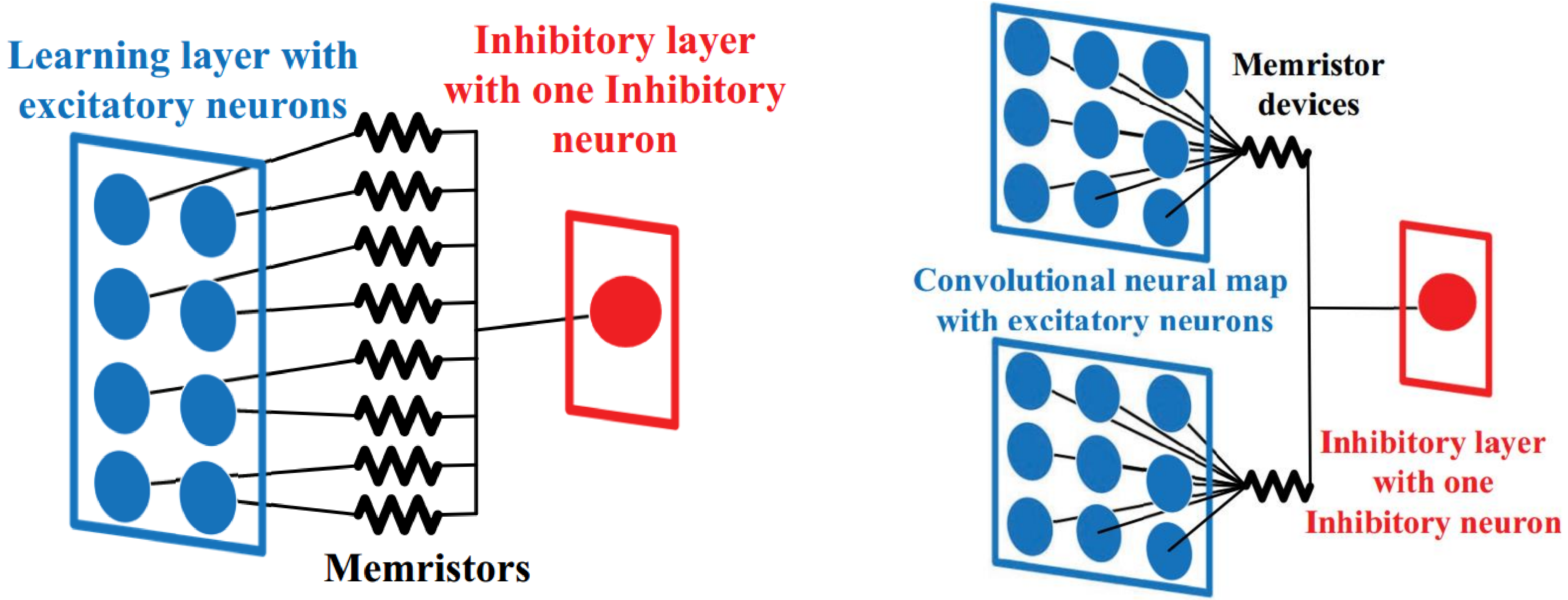



Fig. 8 The network schematics of fully-connected and convolutional SNNs using our proposed method to achieve lateral inhibition and homeostasis.

# 2. Methods

## 2.2 The program mechanism of the memristor in our methods

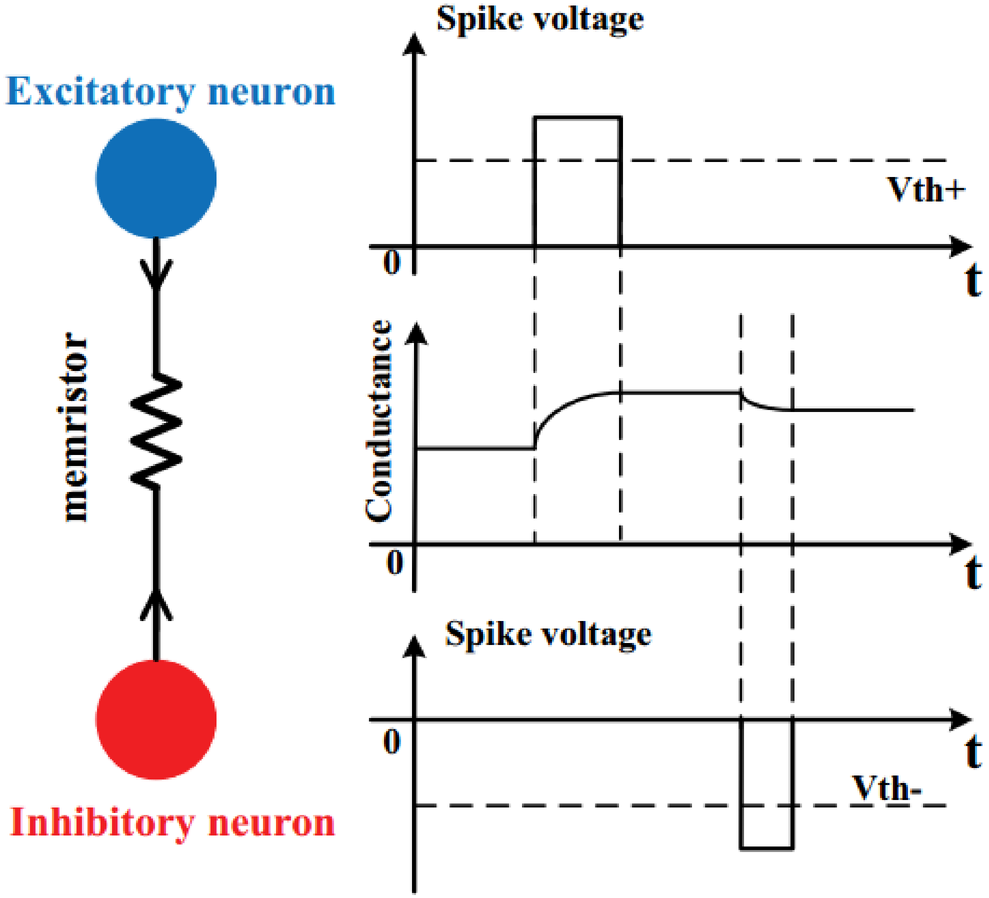


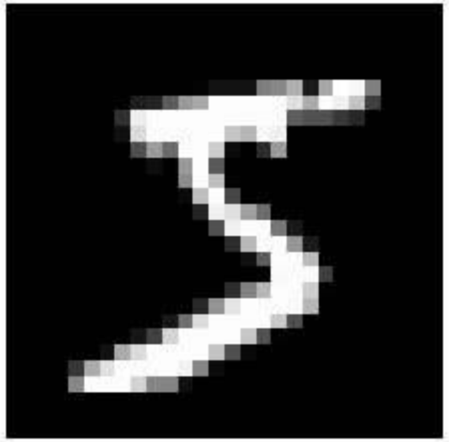

Fig. 9 Conductance variation of the memristor programmed by the transmitted spikes. The increase of conductance programmed by the spike from excitatory neuron is larger than that programmed by the spike from inhibitory neuron.

# 3. Simulation setup

## 3.1 Software and dataset

Software simulations are performed on the open-source simulator of *Brian*.

The widely studied case of MNIST dataset is used as the benchmark task.



In this work, only the fully-connected SNN are simulated for the evaluation of our proposed method.

# 4. Simulation results

## 4.1 Test accuracy comparison

TABLE I
CLASSIFICATION ACCURACIES OF THE PROPOSED SNN WITH TWO UNSUPERVISED SINGLE-LAYER SNNS ON MNIST TEST DATASET

| Neuron number | Querlioz [12] | Diehl [13] | This work |
|---|---|---|---|
| 100 | 85% | 82.9% | 87% |
| 200 | N/A | N/A | 90.5% |
| 300 | 93% | N/A | 91.2% |
| 400 | N/A | 87% | 91.7% |

# 4. Simulation results

## 4.2 Learning speed comparison

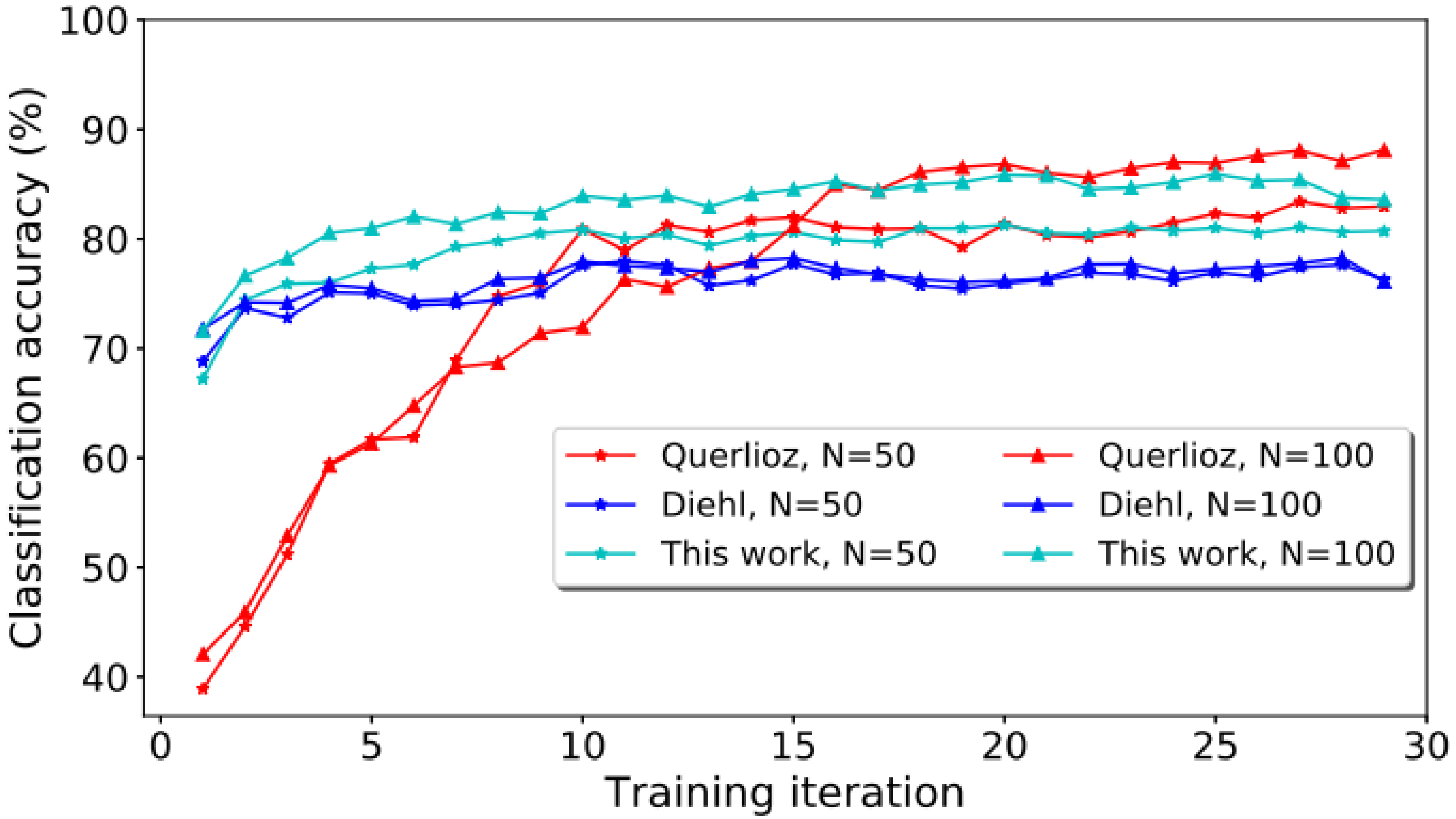



Fig. 10 The test accuracy of three SNNs with with different methods to achieve lateral inhibition and homeostasis after every 2000 training examples.

# 4. Simulation results

国防科技大学
National university of defense technology

## 4.3 Spike number and spike number variation comparison

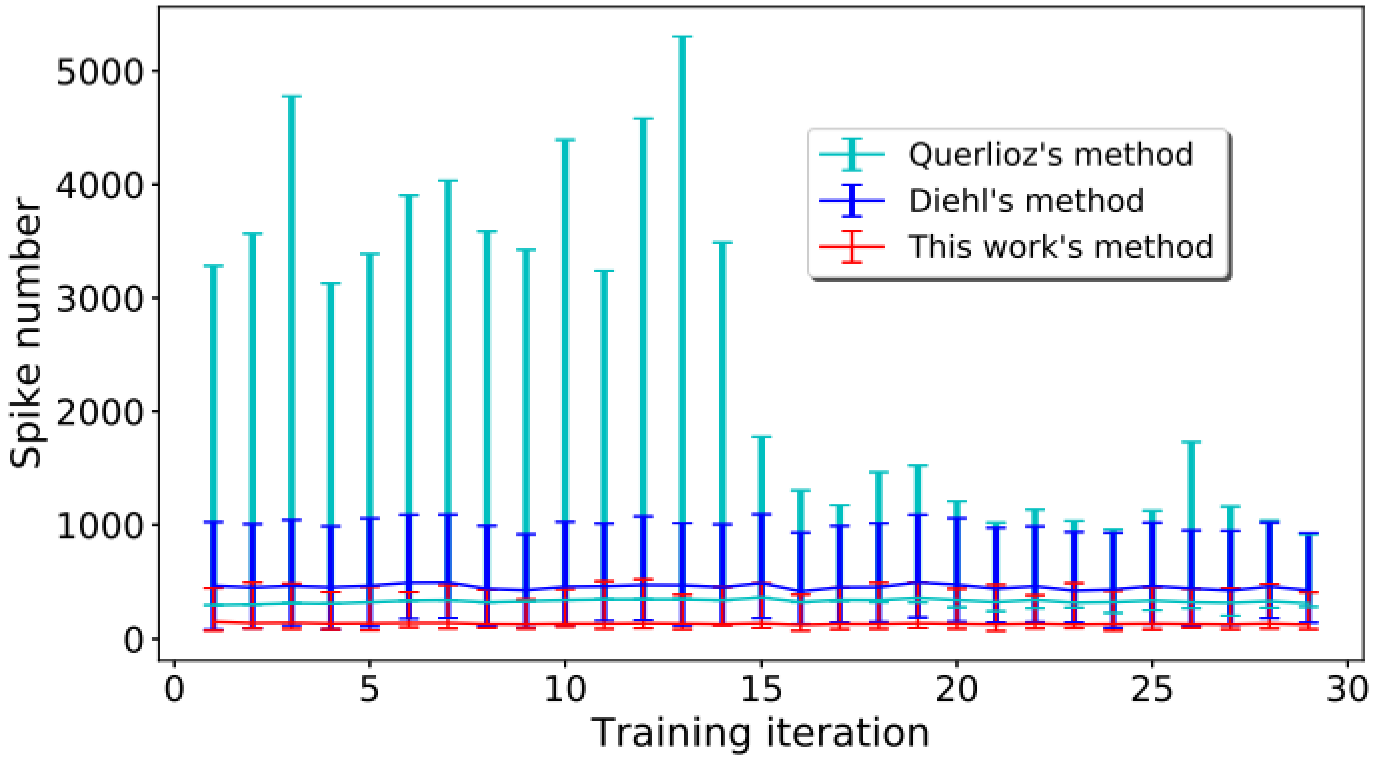



Fig. 11 Spike number and spike number variation of three learning algorithms with different methods to achieve lateral inhibition and homeostasis. The error bar indicates the spike number variation with maximum and minimum spike numbers of all the neurons during one training iteration of 2000 examples.

# 4. Simulation results

## 4.4.1 Robustness to non-ideal device characteristics

TABLE II
CLASSIFICATION ACCURACIES ON MNIST TEST DATASET WITH DIFFERENT NUMBER OF RESISTIVE STATES

| Neuron number | 20 states | 40 states | 60 states | infinite states |
|---|---|---|---|---|
| 50 | 76.9 % | 80.0% | 81.5% | 83% |
| 100 | 82.2% | 84.9% | 85.9% | 87% |

# 4. Simulation results

## 4.4.2 Robustness to non-ideal device characteristics

TABLE III
CLASSIFICATION ACCURACIES ON MNIST TEST DATASET WITH DIFFERENT LEVEL VARIATIONS

| Neuron number | 15% | 25% | 35% | No variations |
|---|---|---|---|---|
| 50 | 80.5 % | 79.3% | 78.3% | 81.5% |
| 100 | 84.9% | 84.4% | 83.5% | 85.9% |

# 4. Simulation results

## 4.4.3 Robustness to non-ideal device characteristics

TABLE IV
CLASSIFICATION ACCURACIES ON MNIST TEST DATASET WITH DIFFERENT DEVICE OPEN PROBABILITY

| Neuron number | 5% | 10% | 15% | No open |
|---|---|---|---|---|
| 50 | 76.76 % | 75.9% | 71.9% | 79.3% |
| 100 | 84.1% | 80.2% | 74.2% | 84.4% |

# 4. Simulation results

## 4.4.4 Robustness to non-ideal device characteristics

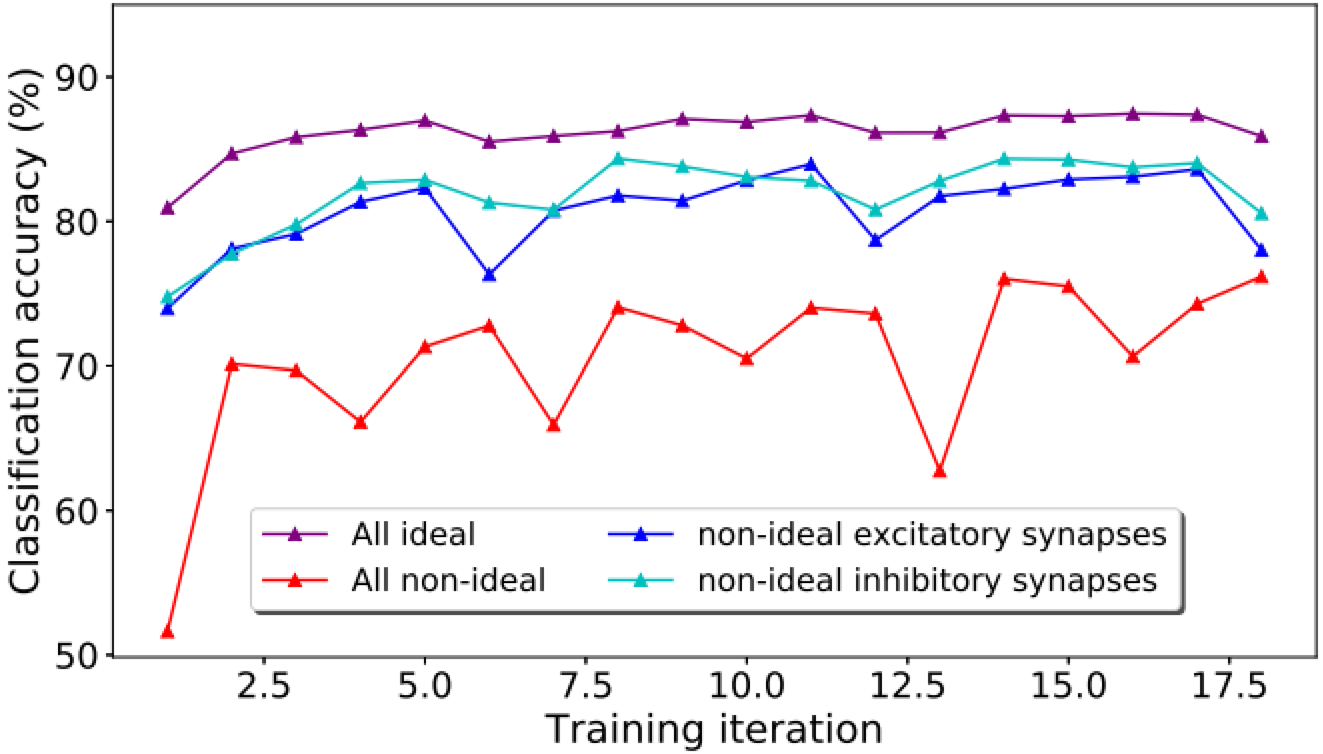



Fig 12. The test accuracy of our proposed SNN with 100 learning neurons after every training iteration of 10000 training examples. Non-ideal device characteristics are applied to all synapses, excitatory synapse, inhibitory synapses, and no synapses in four cases for comparison.

# 5. Conclusion

In this paper, we proposed a SNN using memristor-based inhibitory synapses to achieve lateral inhibition and homeostasis in a compact way.

- For the hardware implementation, our proposed SNN can improve the network scalability by reducing the connection number for lateral inhibition from N^2 to N and decrease the hardware complexity by leveraging the circuit of lateral inhibition to achieve homeostasis.
- Software simulations show that our proposed method can achieve higher learning efficiency (2×) and comparable performance.
- Our approach demonstrates realistic application potential through evaluation considering the non-ideal characteristics of memristor devices.

End!

Thanks !

Q&A?