Third Semester Report

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Project: Electro-mechanical characterization of VO_2 thin film
Ultimate Goal: intelligent sensing that have been researched semesters before

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Von Neumann architecture vs Spiking Neural Network

Von Neumann or Harvard Architecture

Artificial Neural Network: SNN

I would like to contribute to this area of research by *intelligent sensing*

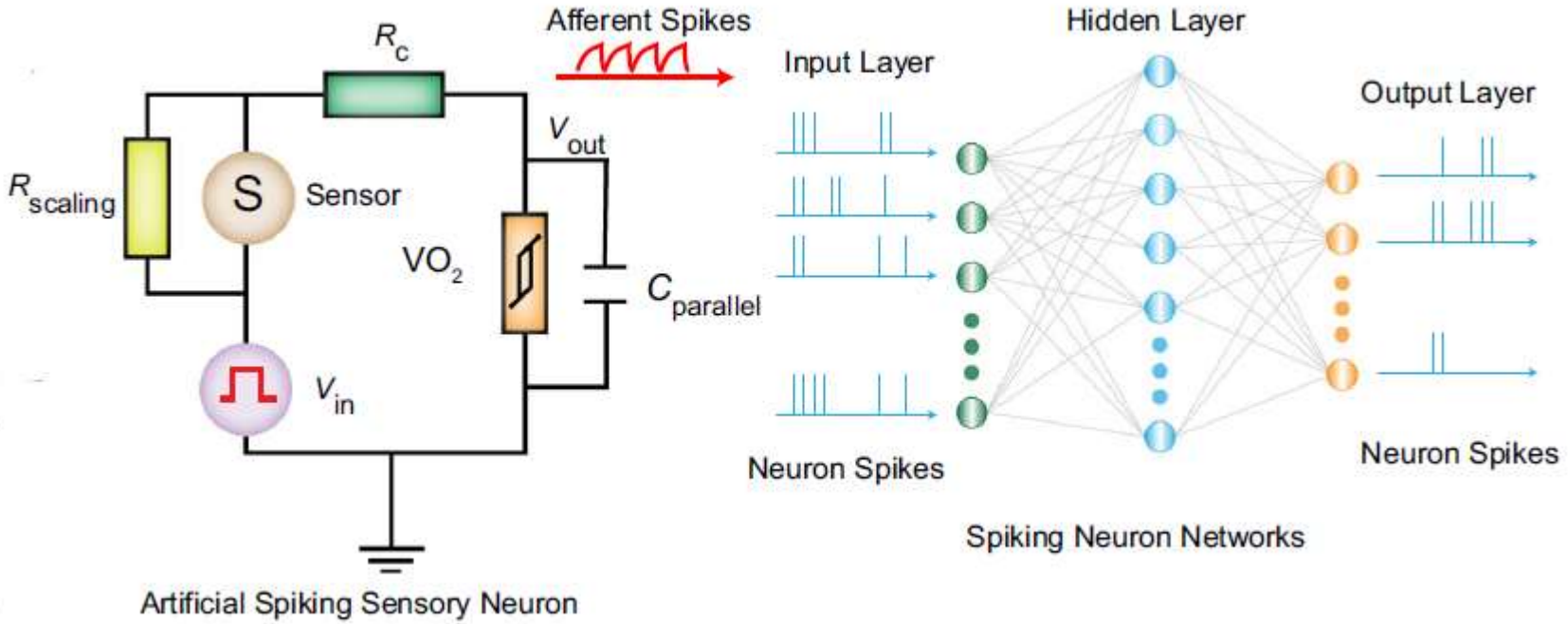
The intelligence of nature provides us with architectural advances

- analogue processing
- keeping time information
- parallel computing
- broader range of applications

Better HW processing elements that needs more intelligent devices from material scientists

- Current transistors are not enough
- More intelligence per unit area needed (vs. cmos neuromorphic circuits)
- More connections
- coms ANNs are expensive in terms of
  - generated heat,
  - size,
  - intelligence per unit area

Example of a Spiking Neural Network[1] (SNN)

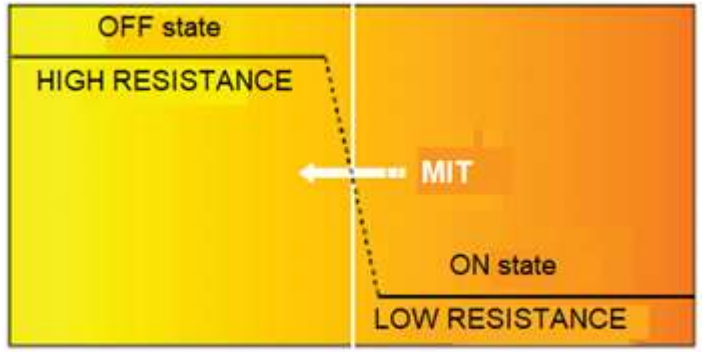


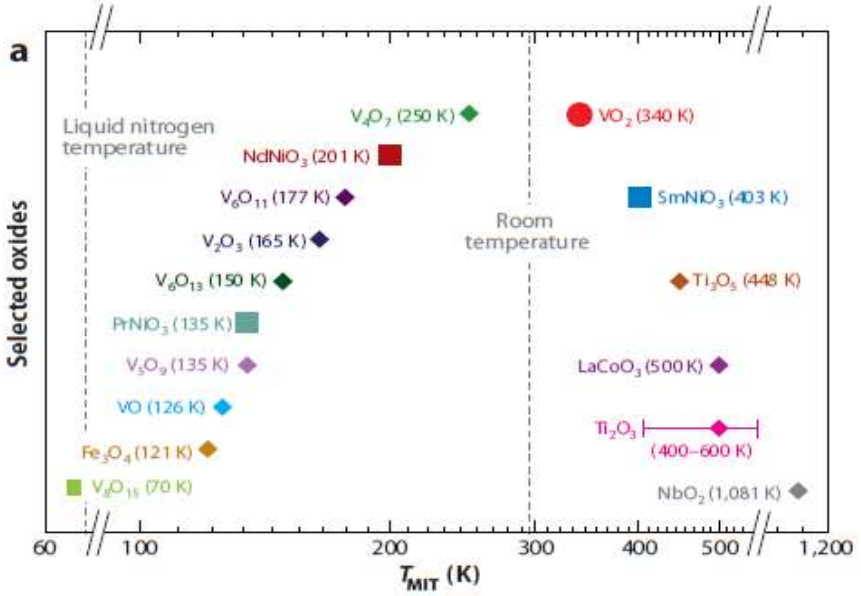
- The heart of the artificial neuron is a vanadium oxide (VO2) device
- Good crystal layer of VO2 can do SPIKES
- Can we make good sensors out of the same VO2; same material, with the same process, on the same chip?

1 A calibratable sensory neuron based on epitaxial VO2 for spike-based neuromorphic multisensory system

Why VO2?

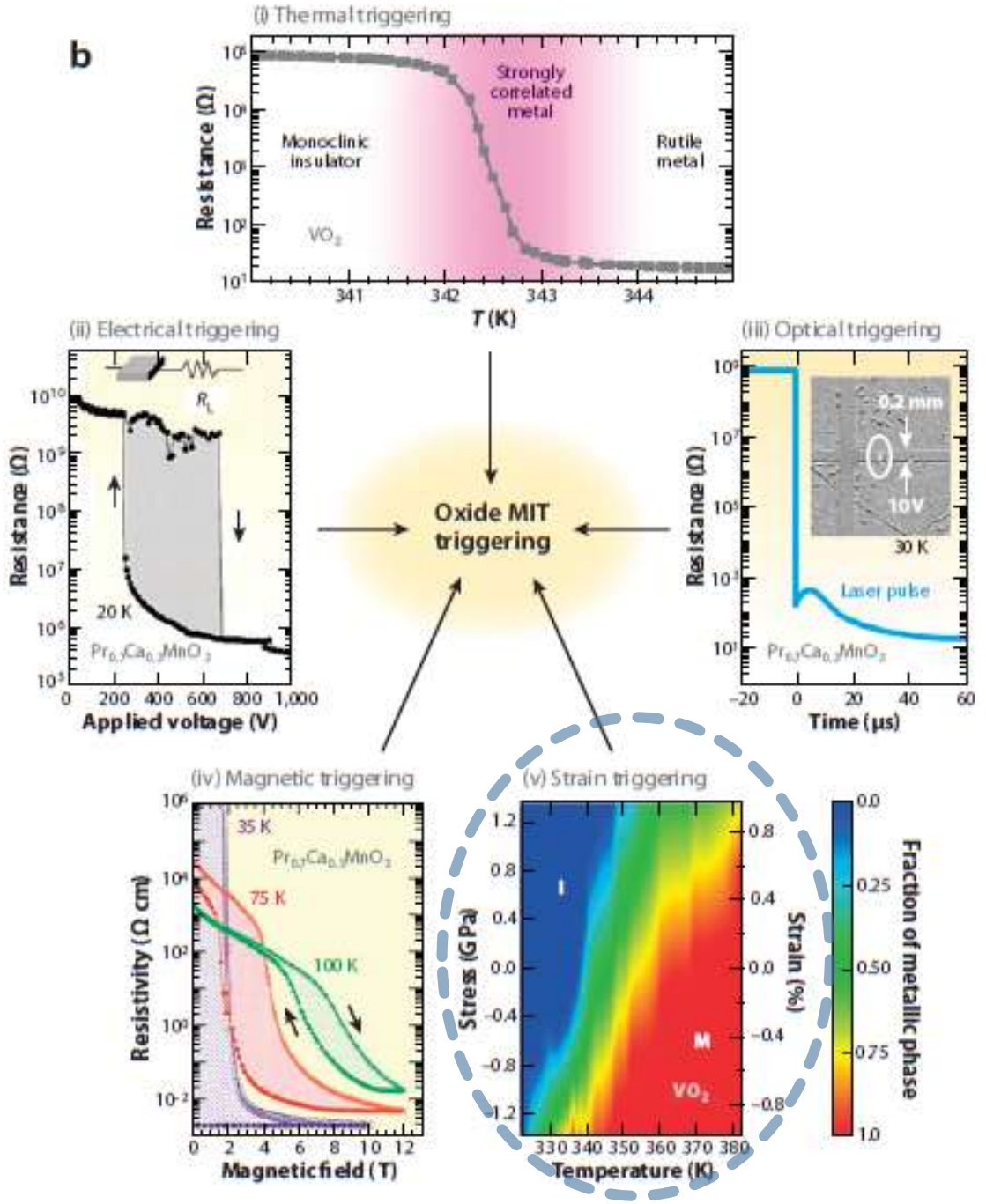
- VO2 transitions from metal to insulator (MIT); tetragonal rutile to monoclinic
- Switches between OFF and ON main states (high and low resistance)
- ultra-fast switching (few hundreds ps)
- high Roff/Ron ratio (up to 4-5 orders of magnitude)
- Low power switching
- Switching temperature is close to room temperature (67 °C) in contrast with other redox materials





Triggering of MITs

- Transition upon a stimulus: Thermal, electrical field, or **strain driven excitation**
- MY GOAL: study the effect of strain on MIT



Structure of VO2

- Has MIM structure (metal-insulator-metal)
- Au-VO_2-Au lateral arrangement switches the device
- Volatile MIT

Conclusions

- device has been fabricated
- I-V curves proves MIT switching
- Run out of test chip, more test is needed, improving upon device OR new process flow OR device structure

Goals

Short term goal:

- After tests of current structure, possible improvements on device (etching, different materials)

Long Term Goal:

- Realization of VO_2 based neuron
- Realization of a VO_2 based Spiking Neural Network
- Integration of sensor and processing functional units based on VO_2 MIT device

Publication List

1. Zeffer, Tamás ; Csikósné, Dr. Pap Andrea Edit
LCD-be integrálható, ujjlenyomat binarizációs képfeldolgozására alkalmas hardver tervezése In: Temesvári, Zsolt (szerk.) XXXVII. Kandó Konferencia Budapest, Magyarország : Óbudai Egyetem, Kandó Kálmán Villamosmérnöki Kar (2021) 138 p. pp. 21-30. , 10 p.

2. David, James ; Montgomery, Benjamin ; James, Hadwen ; Sunay, Shah ; Tamas, Zeffer Method of and apparatus for acquiring an image WO2010024112A1

3. Tamás, Zeffer ; Timót, Hidvégi Reconfigurable Mixed-Signal Neural Network with Embedded Visual Sensing ACTA TECHNICA JAURINENSIS 2 : 2 pp. 277-285. , 9 p. (2009)

4. Zeffer, Tamas ; Yeargan, Jerry Image smoothing and edge detection CMOS sensor array with improved signal output range, In: 2006 IEEE International Conference on Mechatronics, Budapest, Magyarország (2006) pp. 185-188. , 4 p.

5. Zeffer, Tamás ; Hidvégi, Timót, A Programmable Digital Cellular Neural Network Processing On- and Off-Chip Sensory
Information, In: Tavsanoglu, V; Arik, S (szerk.) Proceedings of the 2006 10th IEEE International Workshop on Cellular Neural Networks and Their Applications, Istanbul, Törökország, Piscataway (NJ), Amerikai Egyesült Államok : IEEE (2006) pp. 53-56. , 4 p.

6. Zeffer, Tamás ; Hidvégi, Timót, The Configurable Digital Neural Network with Emulated Digital Cellular Neural Network Cores, In: IEEE (szerk.) 2006 IEEE International Conference on Mechatronics, Piscataway (NJ), Amerikai Egyesült Államok : IEEE (2006) 638 p. pp. 160-164. , 5 p.

7. Zeffer, Tamás ; Hidvégi, Timót; The Con gurable Digital Cellular Neural – Hopfield Network; In: IEEE (szerk.) INES 2006 10th International Conference on Intelligent Engineering Systems; New York, Amerikai Egyesült Államok : IEEE Press (2006) 316 p. pp. 160-164. , 5 p.
DOI IEEE Xplore

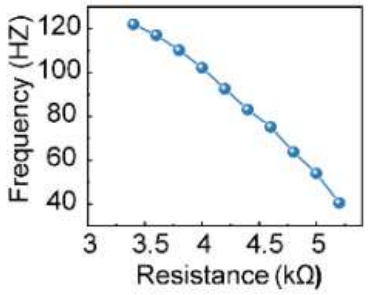
8. Zeffer, T.; A two-dimensional CMOS sensor array. (Research report of the Analogical and Neural Computing; Laboratory DNS-4-2004) (2003)

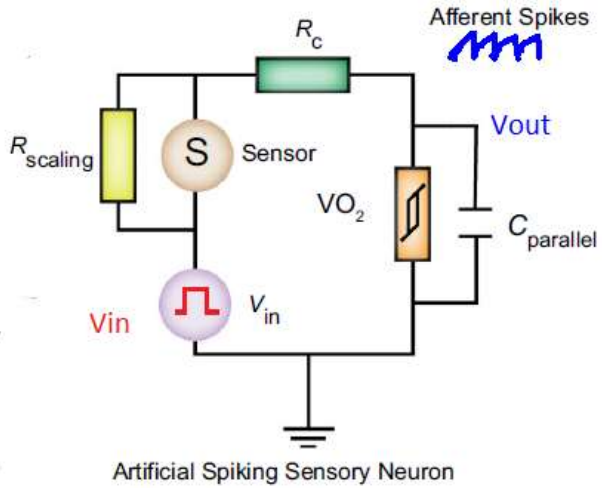
Thank you

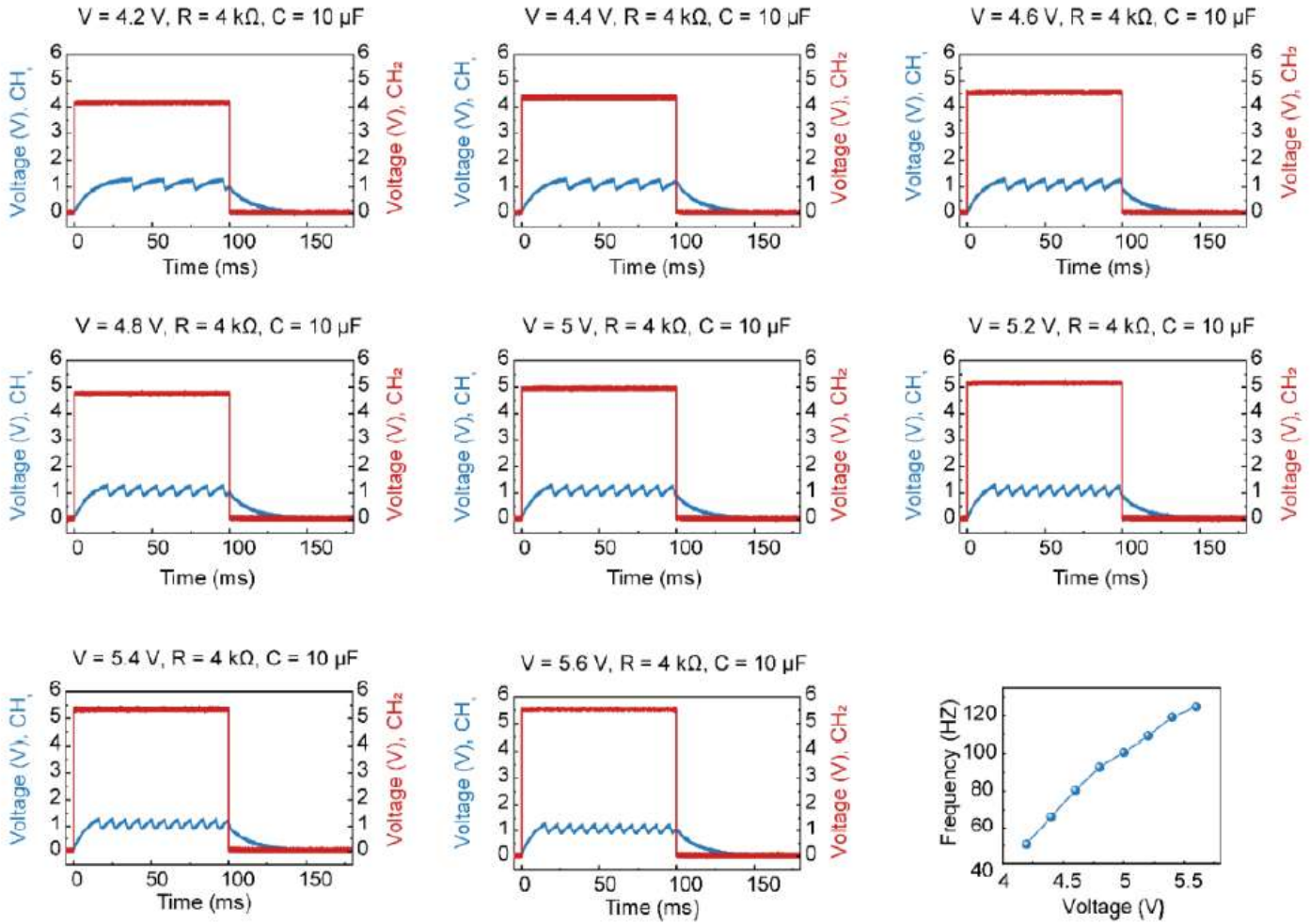
Questions

Example of a Spiking Neural Network (SNN) sup.

BACK

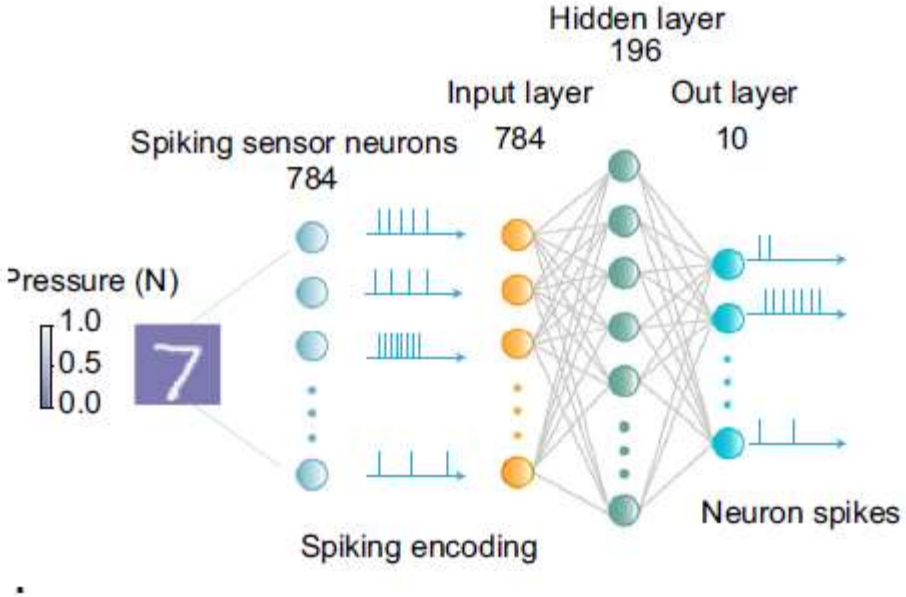


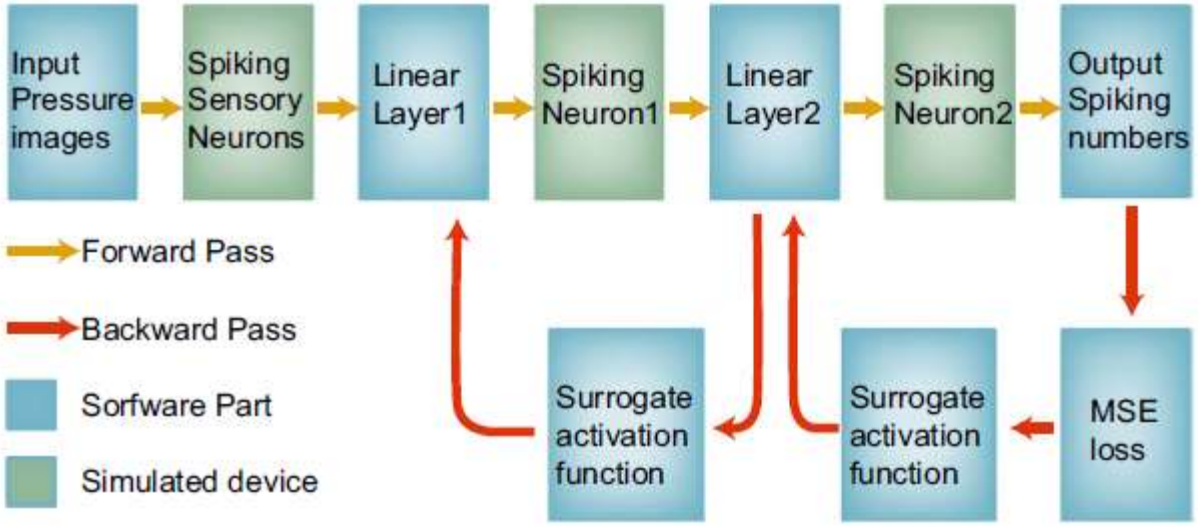




Inputting Sensory Pressure Image and simulated device data into SNN Software: SpikingJelly

BACK


Hidden layer
196
Input layer
784
Out layer
10
Spiking sensor neurons
784
Pressure (N)
1.0
0.5
0.0
7
Neuron spikes
Spiking encoding


Input Pressure images
Spiking Sensory Neurons
Linear Layer1
Spiking Neuron1
Linear Layer2
Spiking Neuron2
Output Spiking numbers
Forward Pass
Backward Pass
Sorfware Part
Simulated device
Surrogate activation function
Surrogate activation function
MSE loss