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TRAIL Annual Event 2024

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Inclusion, Parsimony & Plurality: The future of AI?

Spiking Neural Networks:
A new energy-efficient type of artificial neural network

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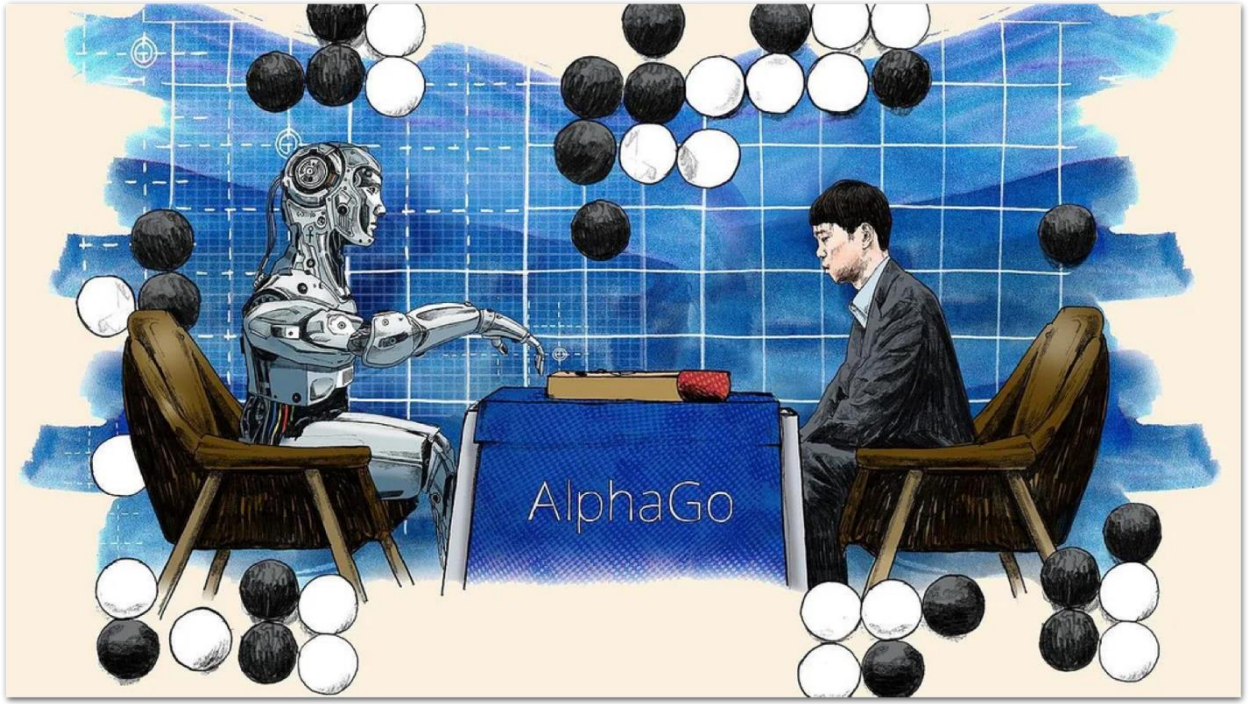
Current AIs are performant
But not energy-efficient

AlphaGo:
± 1 Megawatts

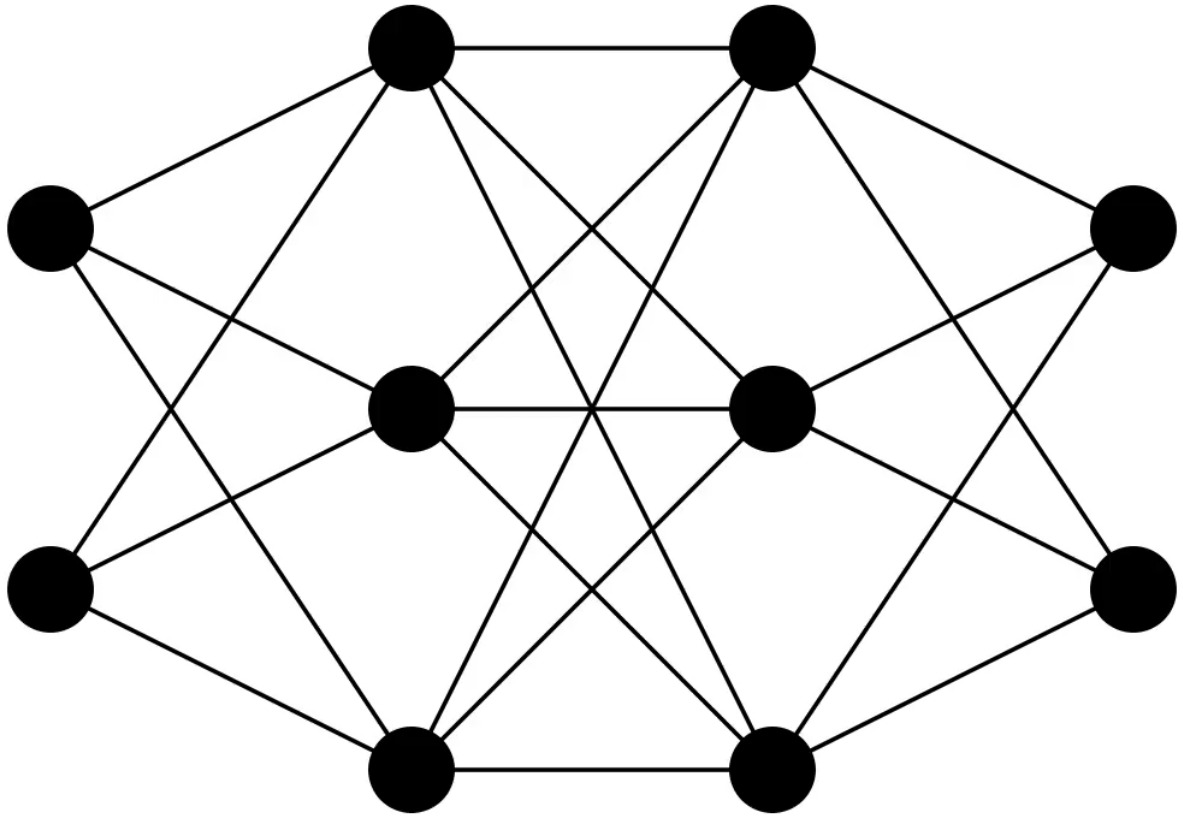


L. Sedol's brain:
± 20 Watts

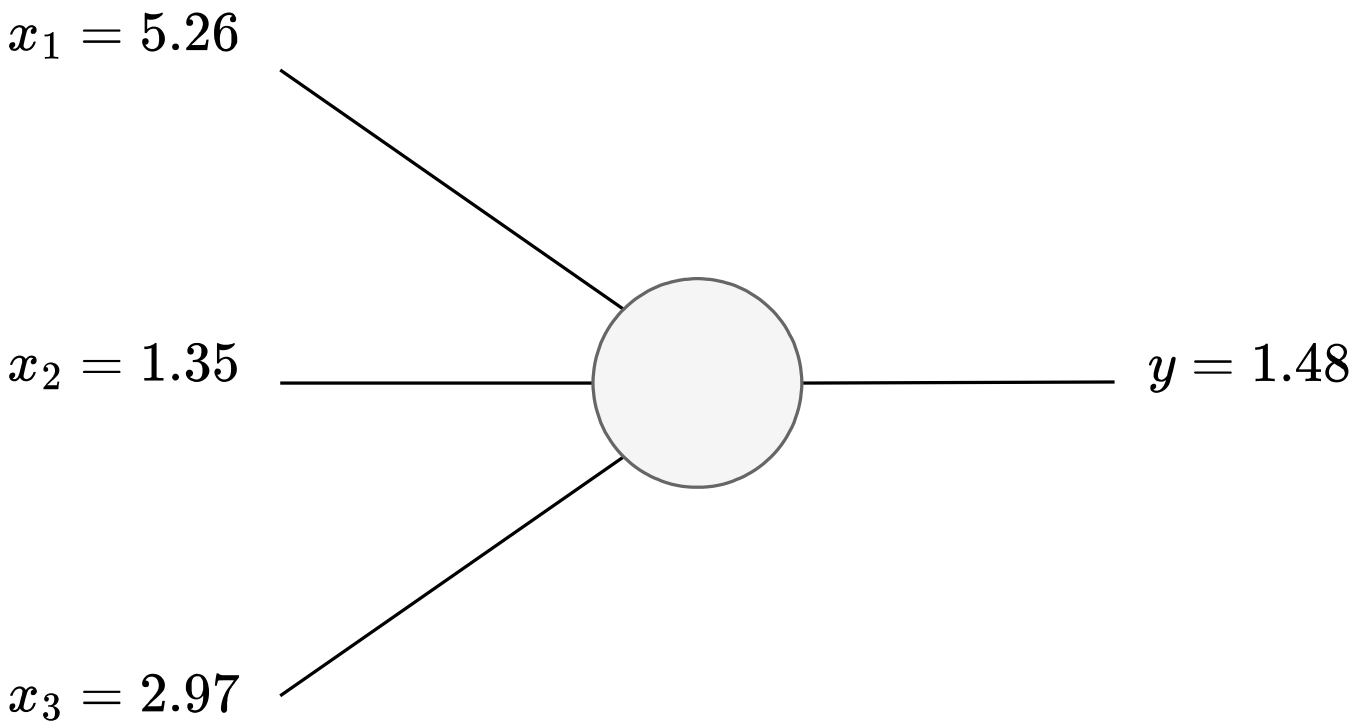
Need better energy-efficiency in some applications (e.g., embedded systems)

data: jacquesmattheij.com/another-way-of-looking-at-lee-sedol-vs-alphago, image: reddit.com/r/baduk

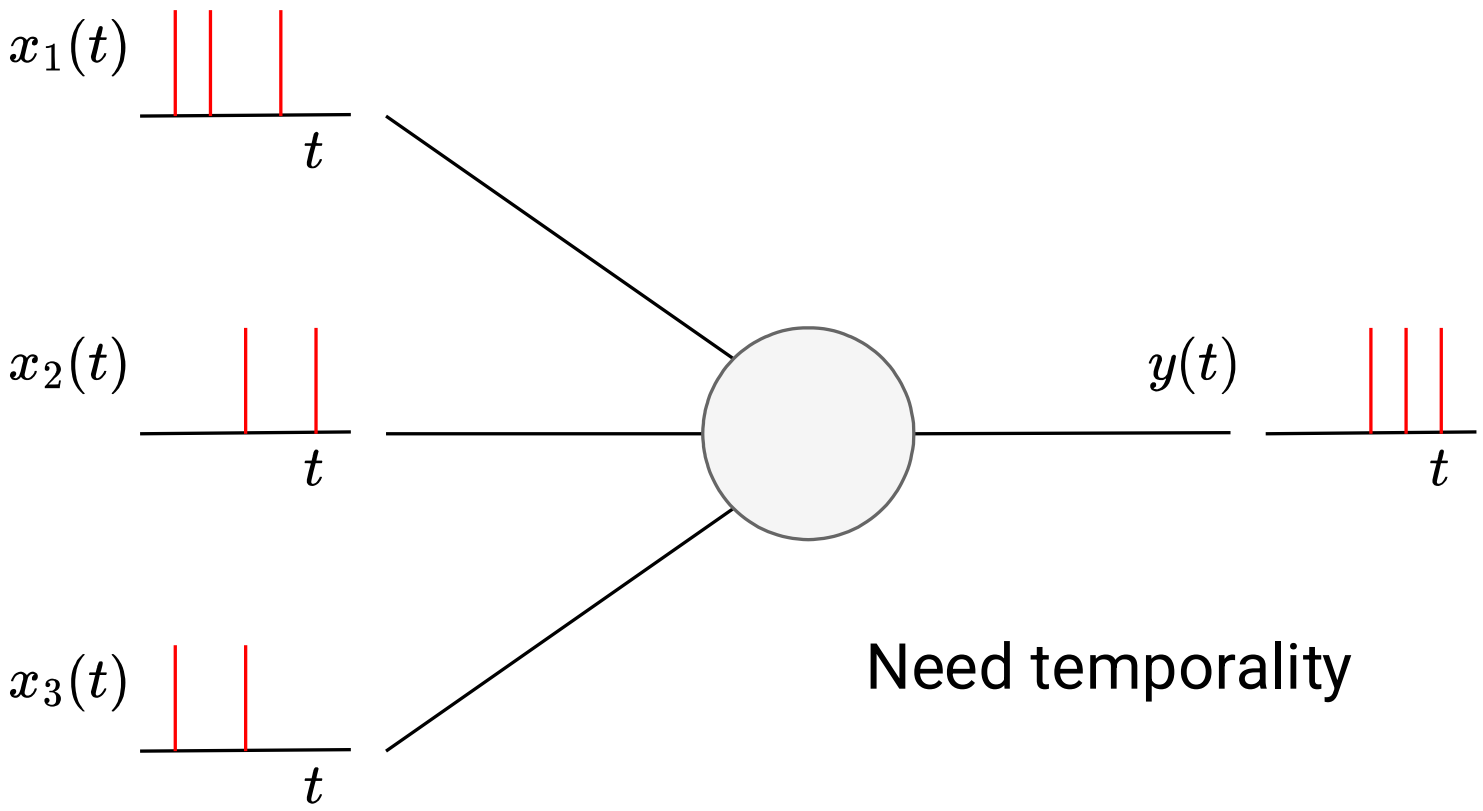
Artificial neurons are clock-driven, Biological neurons are event-driven



Artificial neurons output numbers,



Artificial neurons output numbers, Biological neurons output events



Need temporality

Can build neural networks with such neurons ⇒ Spiking Neural Networks (SNNs)

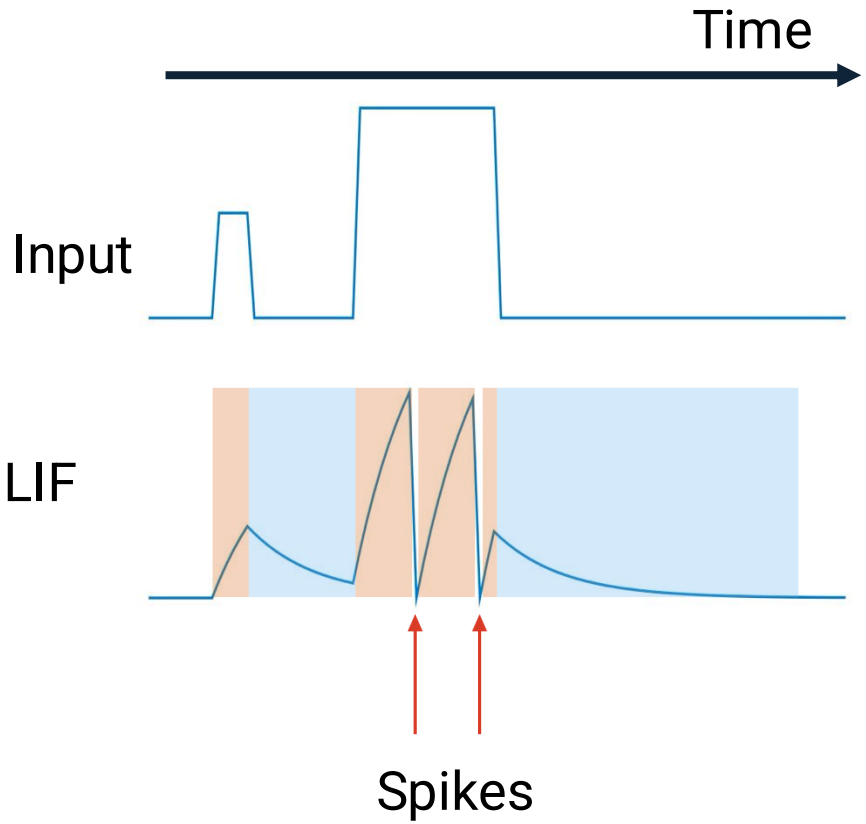
LIF neurons are (usually) used in SNNs

LIF = Leaky Integrate-and-Fire

Very simple model:

- Integrates when input
- Leaks when no input
- Fire if above threshold
  - Non-differentiable operation

Add learning weights and you have your artificial spiking neuron



SNNs are hard to train due to the non-differentiability of LIF

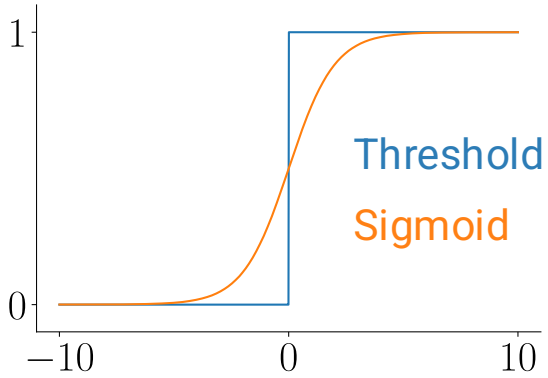
Cannot applied usual backpropagation

Three main ways to train SNNs:

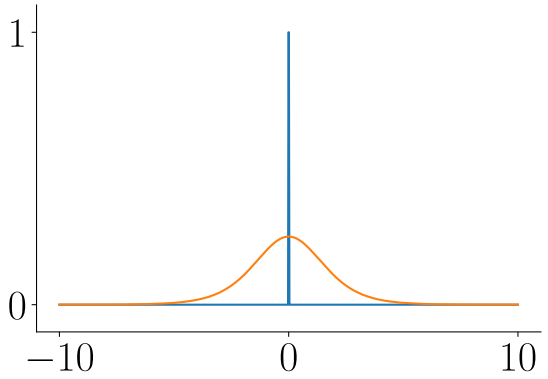
- Bio-inspired learning
- ANN-to-SNN conversion
- Backpropagation with surrogate gradient

SNNs are not as good as ANNs on complex benchmarks

Activation:



Derivative:



SNNs are energy-efficient… when run on specific hardware

No gain in energy-efficiency if run on classical hardware

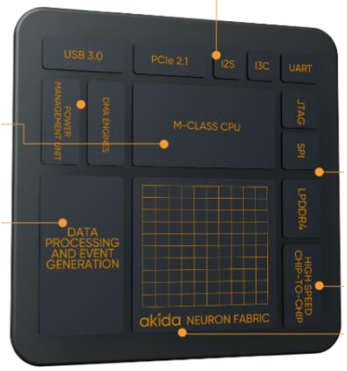
Needs *neuromorphic* hardware

Energy consumption:

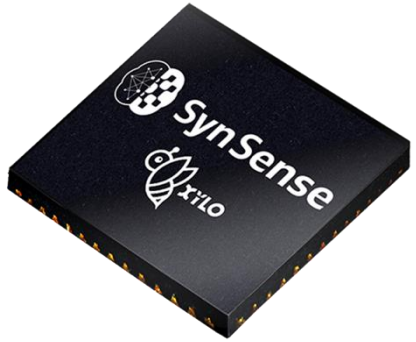
- Less than 1W for Loihi 2
- For ± 1 million neurons

Loihi 2 (Intel)

Speck (SynSense)



Akida (BrainChip)



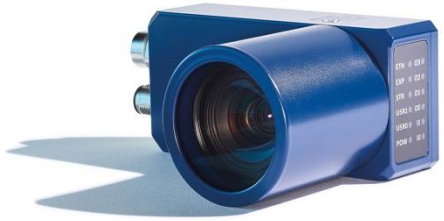
Xylo (SynSense)

SNNs are the heart of neuromorphic computing

Neuromorphic computing

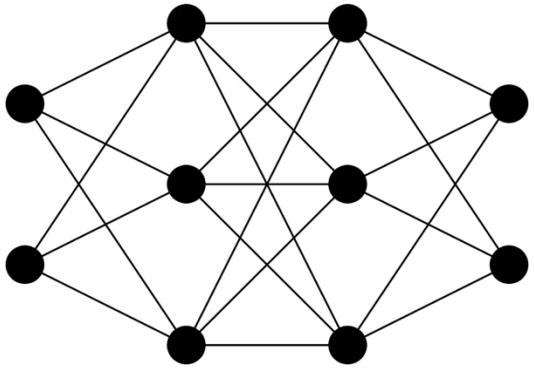
Mimicking the structure and the operation of the brain to:

Sense



Event-based camera

Process



SNNs

Act

Robotic hand

hand: shadowrobot.com/dexterous-hand-series/, camera: prophesee.ai/2019/02/14/imago-prophesee/

A concrete example:
The Mercedes Vision EQXX concept car

EV concept car with a range of more than 1000km

To increase range,
decrease energy consumption

Use a SNN to efficiently detect the “Hey Mercedes” hot word

eetimes.com/mercedes-applies-neuromorphic-computing-in-ev-concept-car/

A quick word about my research

LIF neurons are used in SNNs

But they do not capture the rich dynamics of biological neurons

There exist better models in computational neuroscience

- But these are too complex to be used in neural networks…

So, we created a new spiking neuron that:

- Is simple like LIF
- Can capture the dynamics of neurons

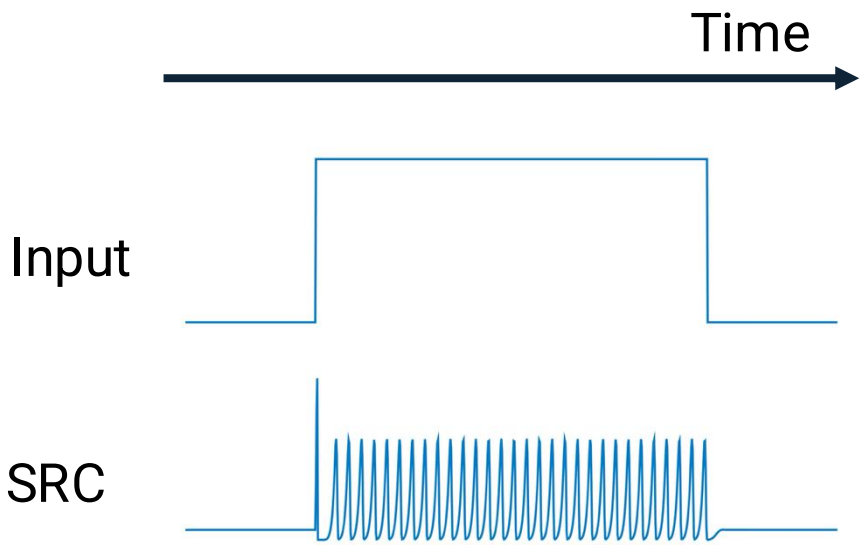
The Spiking Recurrent Cell (SRC)

Is derived from recurrent neural networks

Can be trained like usual SNNs

Generate spikes by itself

- No need of hard threshold



The Spiking Recurrent Cell (SRC)

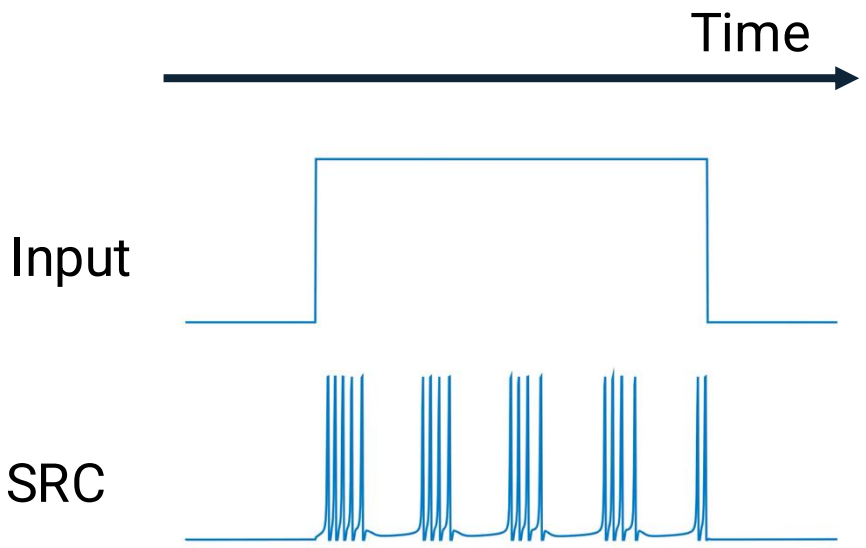
Is derived from recurrent neural networks

Can be trained like usual SNNs

Generate spikes by itself

- No need of hard threshold

Can easily exhibit new firing patterns



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Thank you all for your attention!

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