HIERARCHICAL TEMPORAL MEMORY

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HTM

- HTM is a theoretical framework for both biological and machine intelligence.
    - Based on the Neocortex
- Deep Neural Nets (DNN) have clocked up incredible successes in many areas,
    - DNN needs thousands if not millions of samples to train on
    - DNN finds it hard to adapt to continually changing data and surprises
    - DNN is not a good fit in such problem domains, such as sensorimotor
- In contrast, HTM
    - HTM only requires a few hundred samples to learn
    - HTM learns unsupervised as it goes and easily handles changing data and surprises

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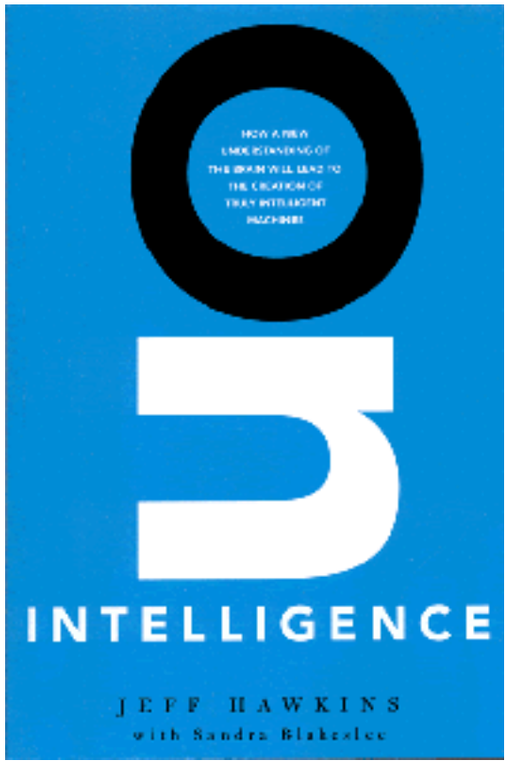
History



- 2004 “On Intelligence” by Jeff Hawkins & Sandra Blakeslee
    - The core concepts in Hierarchical Temporal Memory (HTM) theory were first described in this book
- 2005 Numenta was established in Redwood City, CA to
    - understand and model the human neocortex
    - enable technology based on cortical theory
- 2014 NuPIC (**Nu**menta **P**latform for **I**ntelligent **C**omputing) was open sourced under the AGPLv3 license
    - API in Python 2.7, Java and C++
    - Third Party Implementations in Closure, C#
    - Community port to Python 3 (in progress)

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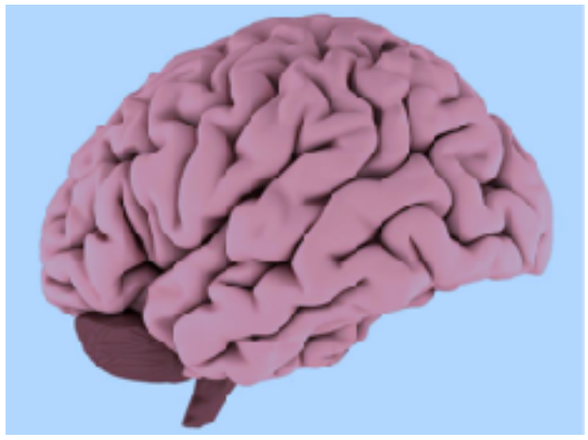
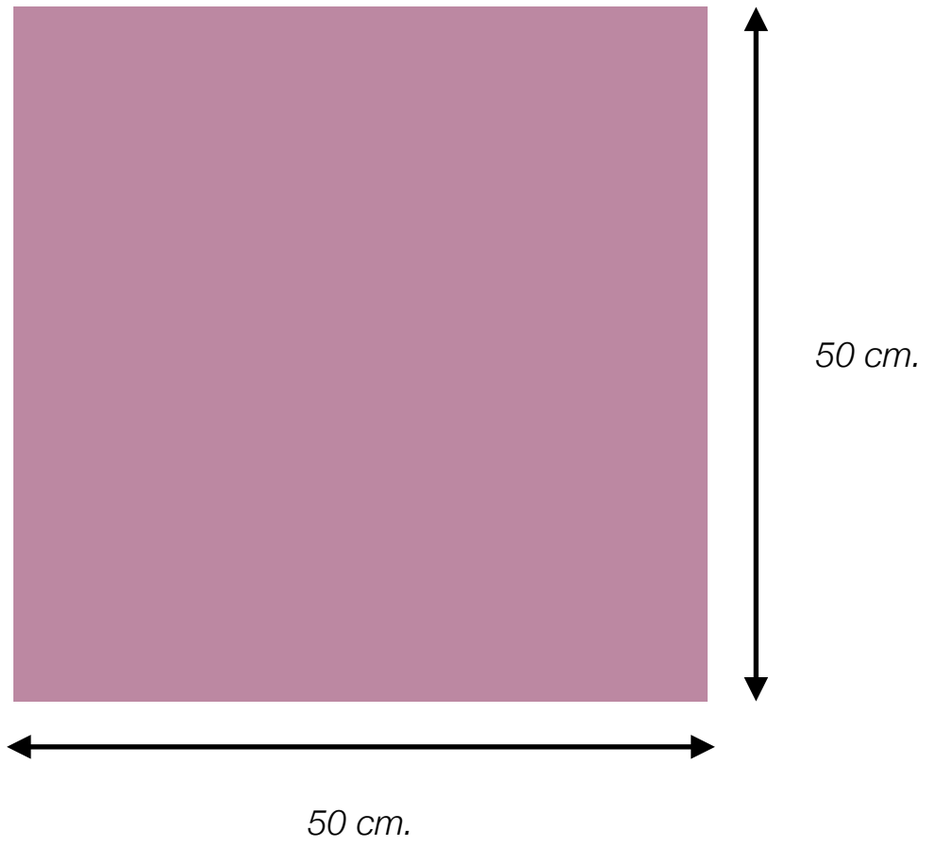
Neocortex

- Size of a large table serviette (50x50 square centimetres)
- 2.5 mm thick
- 30 billion neurons
- 10 thousand synapses per neuron
- -> 300 trillion edges (in a graph)



- Largely homogenous
    - Replication of same neural algorithms
        - packaged into cortical columns
- Sparsely active
    - Only ~ 2% spiking at any one time
- Constantly predicting its inputs



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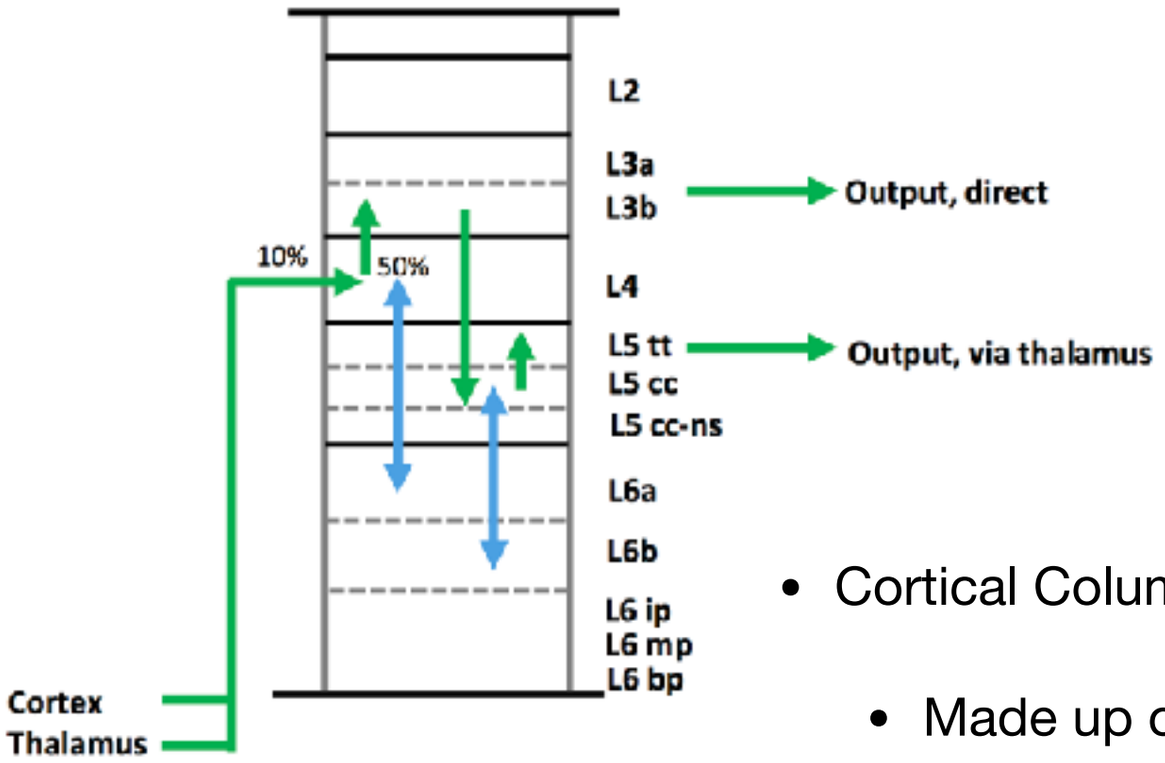
Cortical Column



- Cortical Columns are complex
  - Made up of cellular “mini-columns”
    - 12 or more cellular layers
    - 2 parallel feed forward pathways
    - Parallel feedback pathways (not shown)
    - Numerous intra and inter column pathways (not shown)
- So whatever the column does must also be complex
- Whatever the column does applies to everything the neocortex does.

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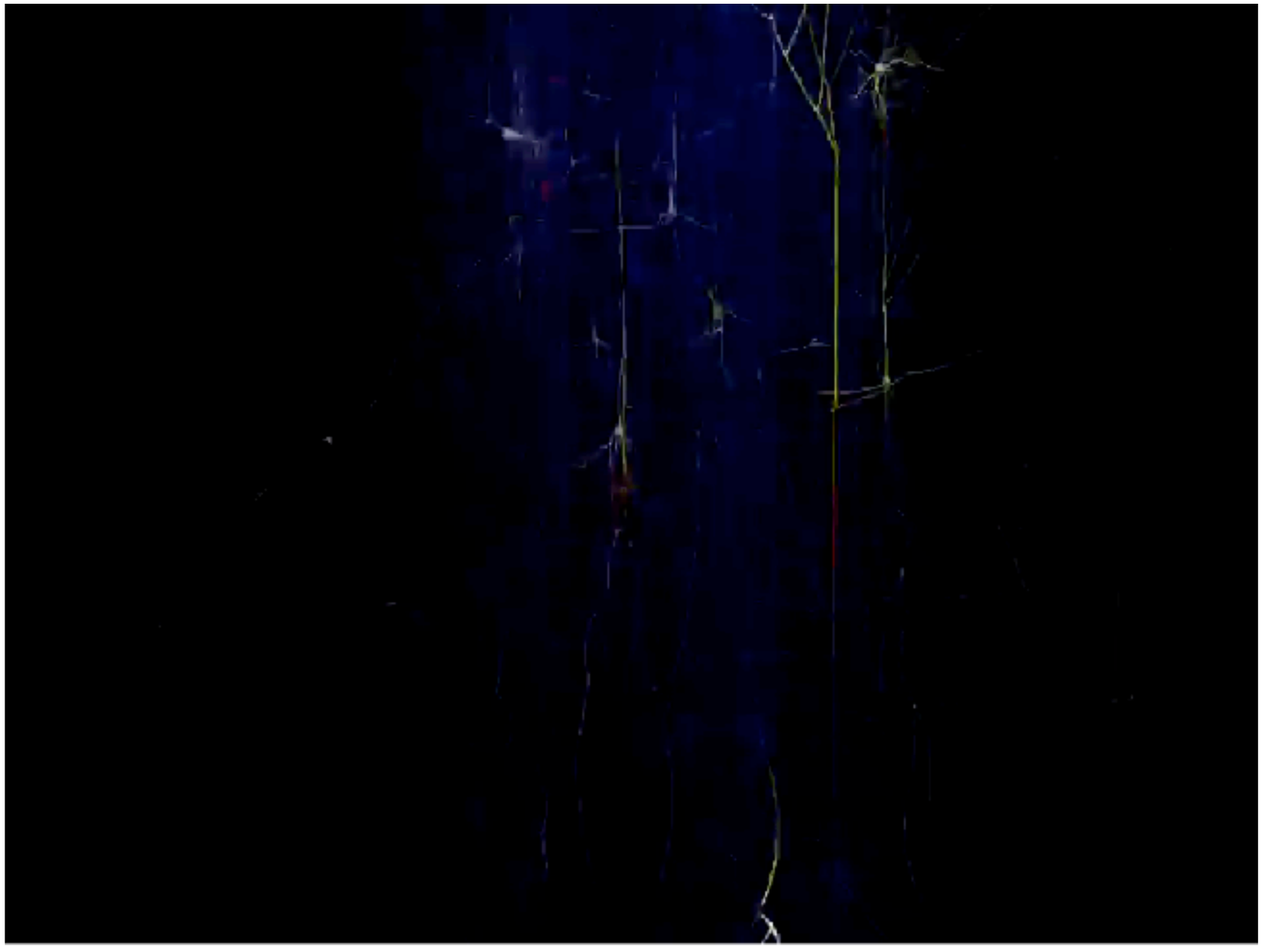
Visualisation



http://cajalbbp.cesvima.upm.es/

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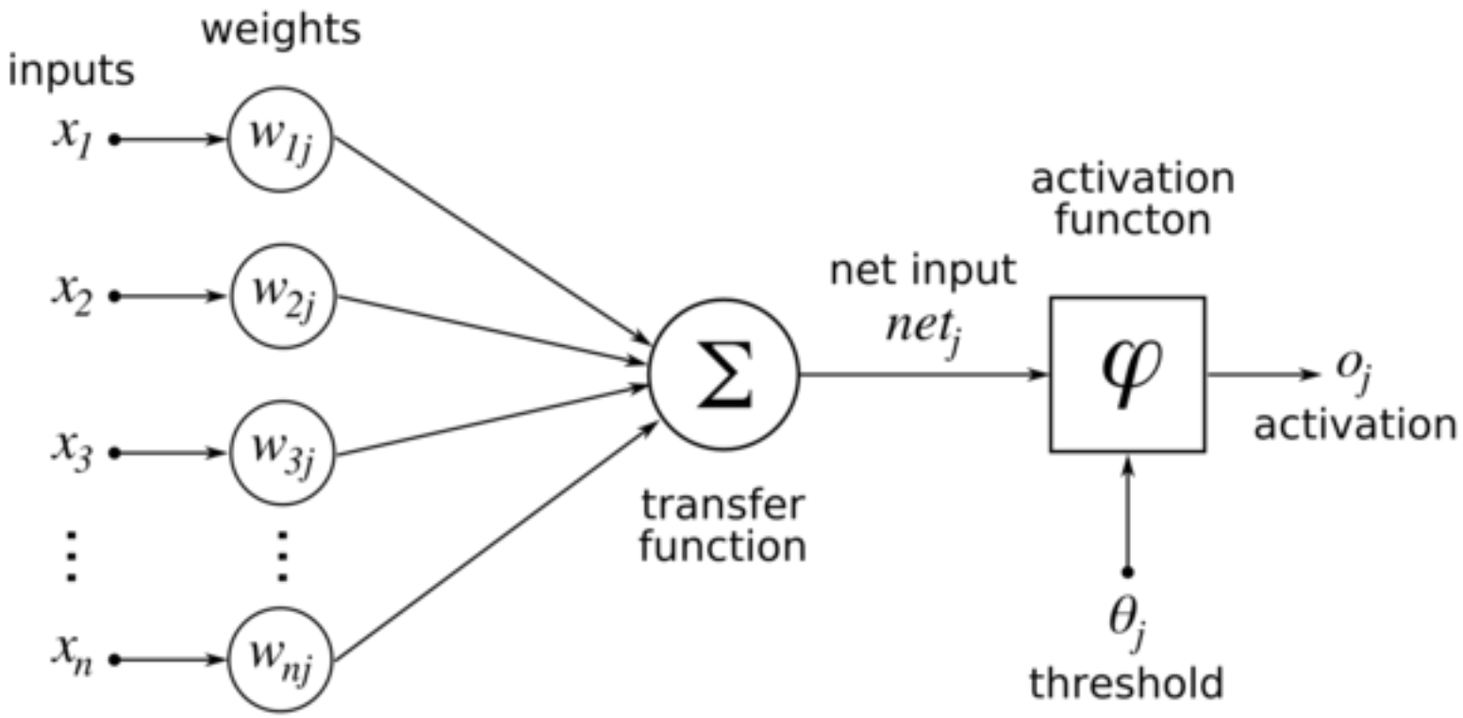
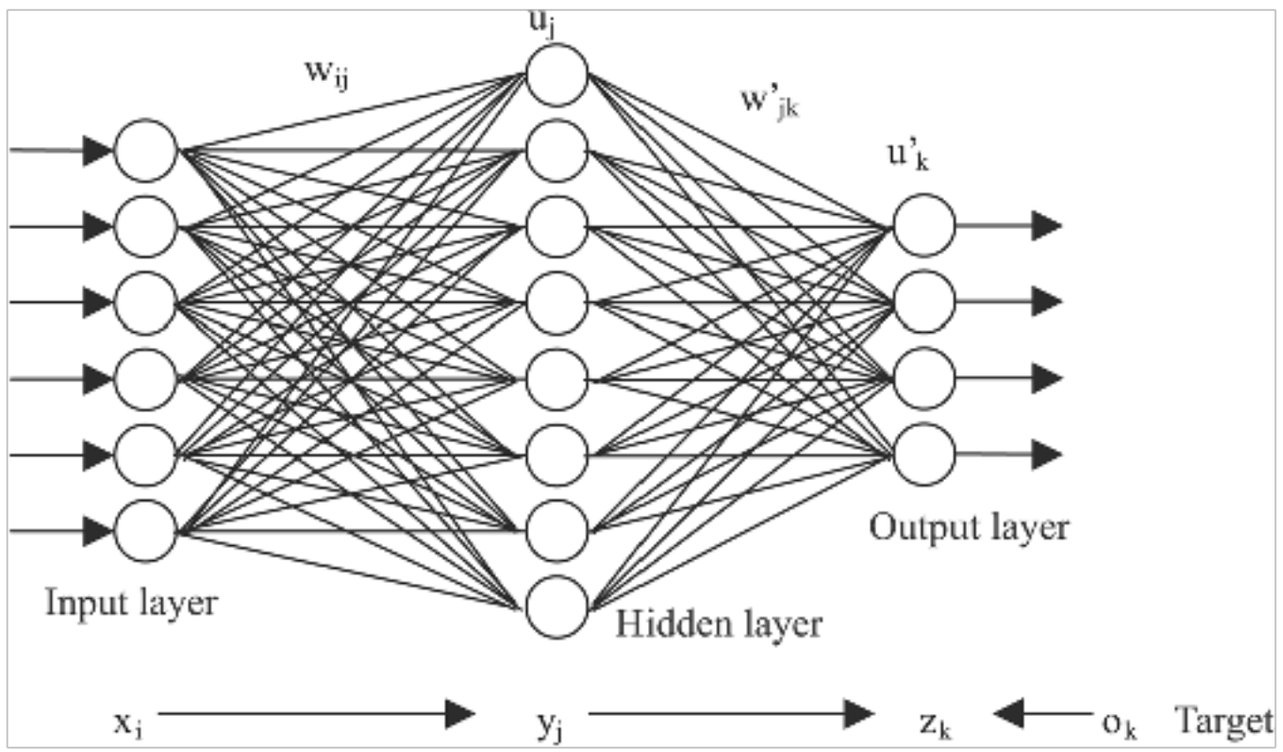
Deep Neural Net Neuron





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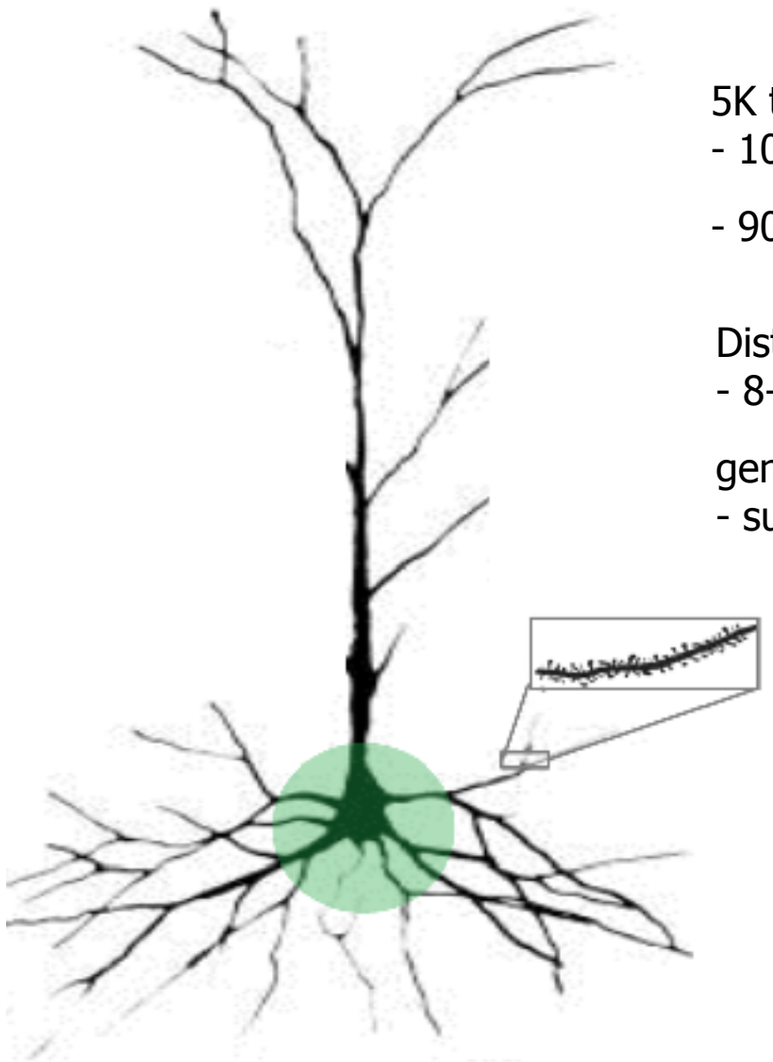
HTM Neuron

Real Neuron



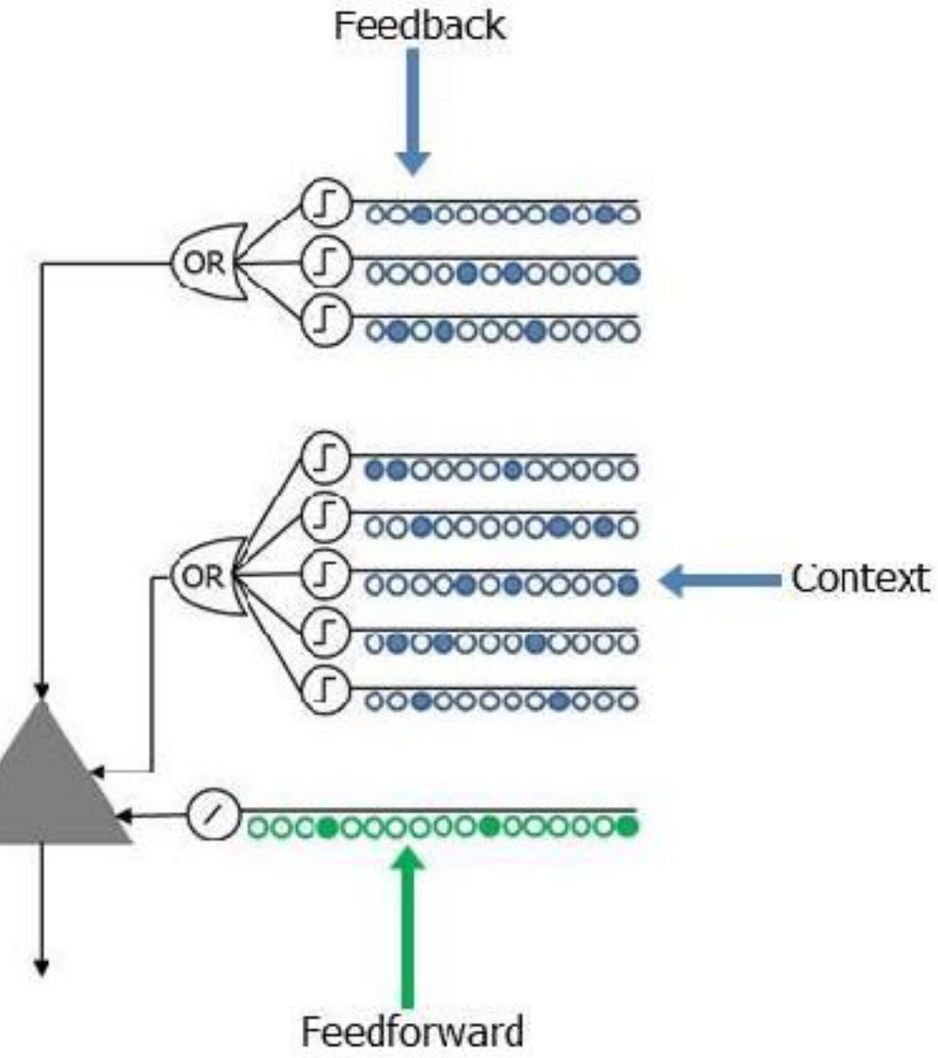
5K to 30K excitatory synapses
- 10% proximal, can cause spike

- 90% distal, cannot cause spike

Distal dendrites are pattern detectors
- 8-15 co-active, co-located synapses

generate dendritic spike
- sustained depolarisation of soma

HTM Neuron Model



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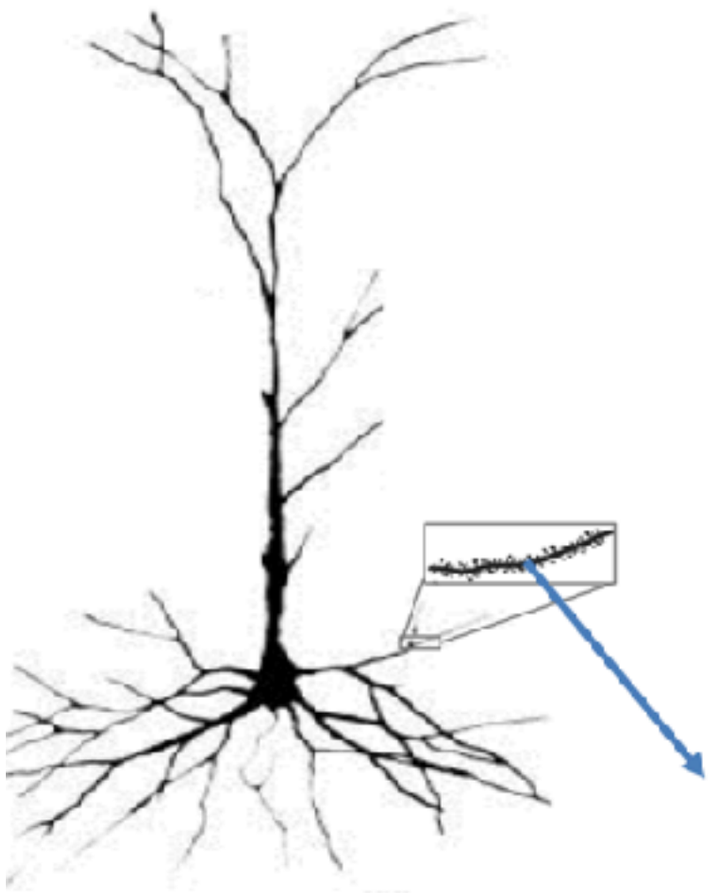
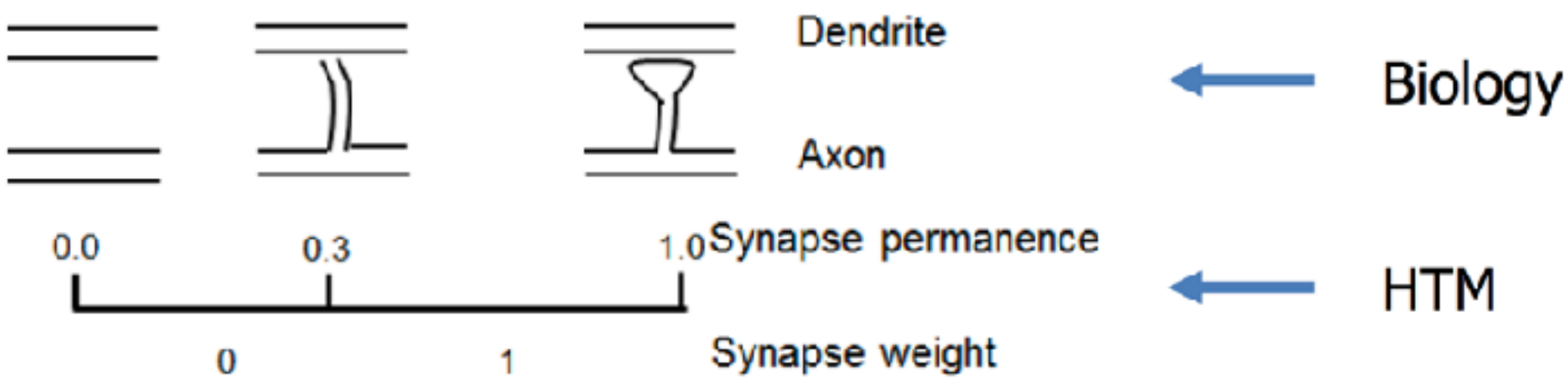
Learning is by Rewiring, Forming New Synapses Not by Changing Synaptic Weights



Synapses are binary connectors:
either they are connected or they are not!



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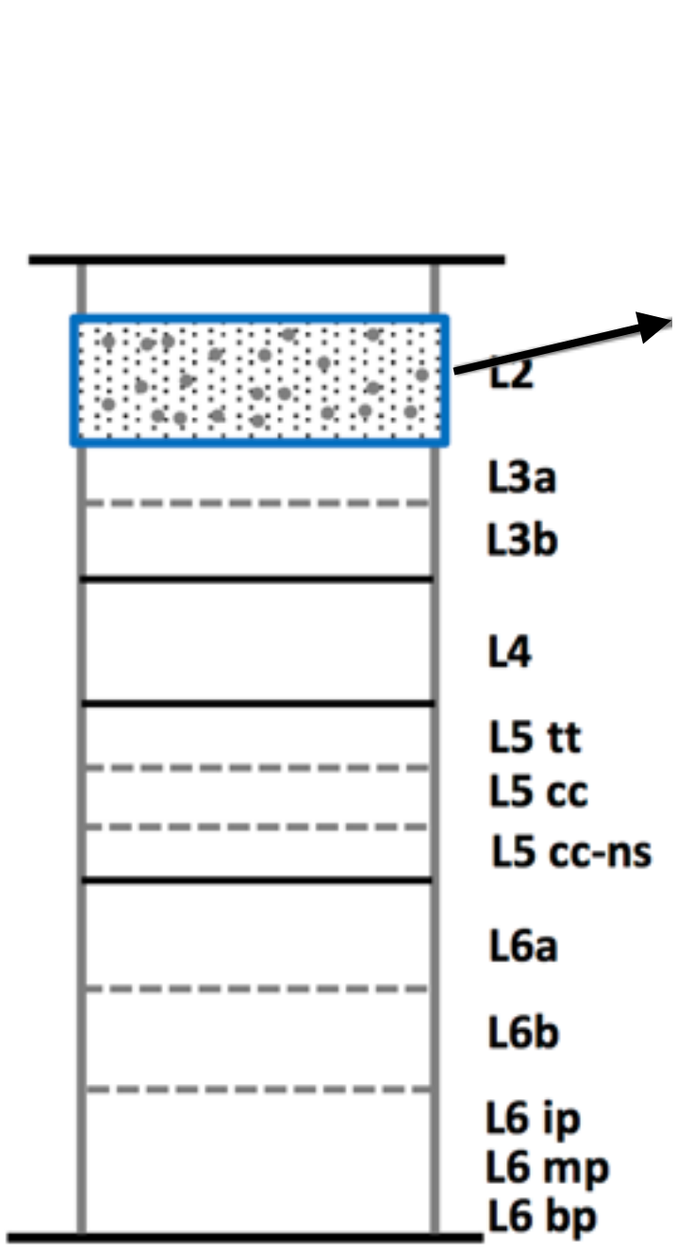
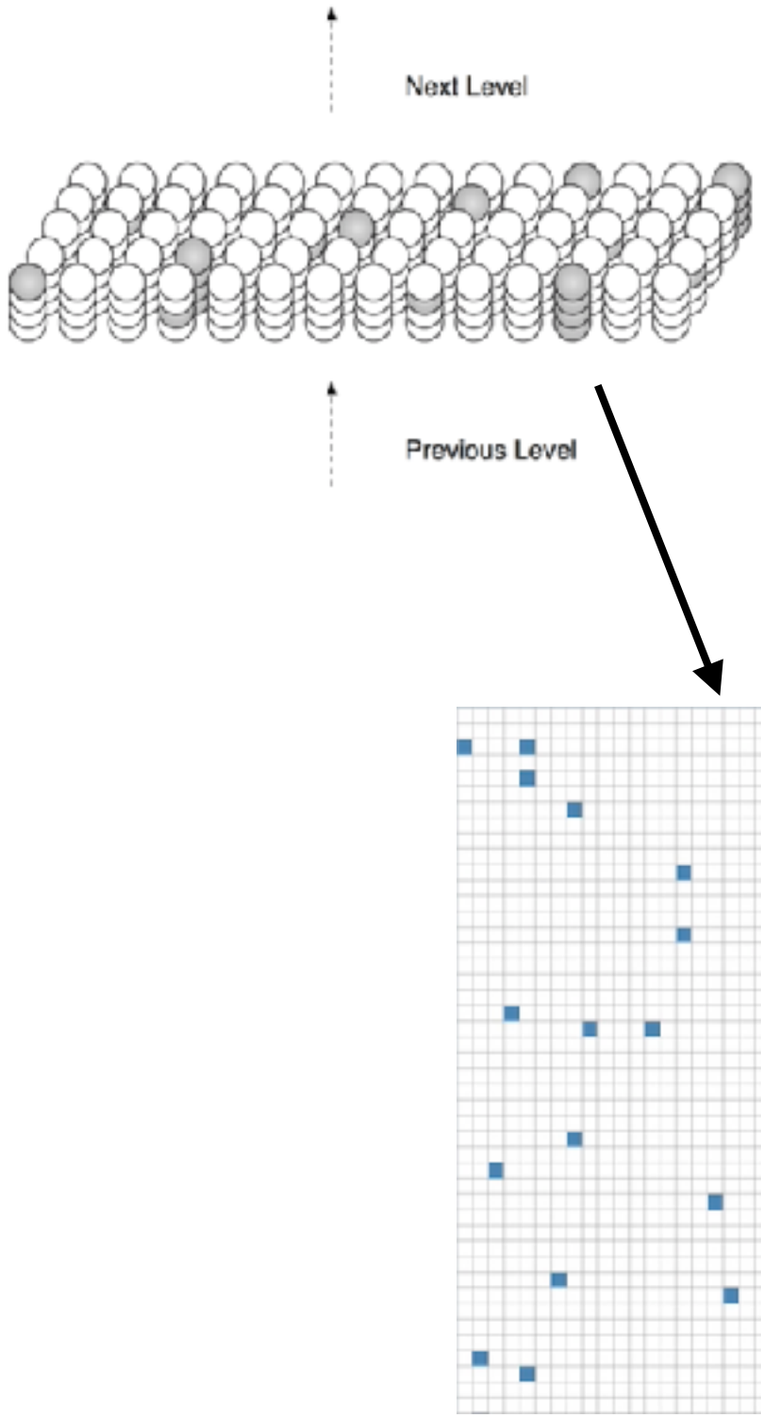
HTM Cortical Column





Sparse Distributed Representation (SDR)

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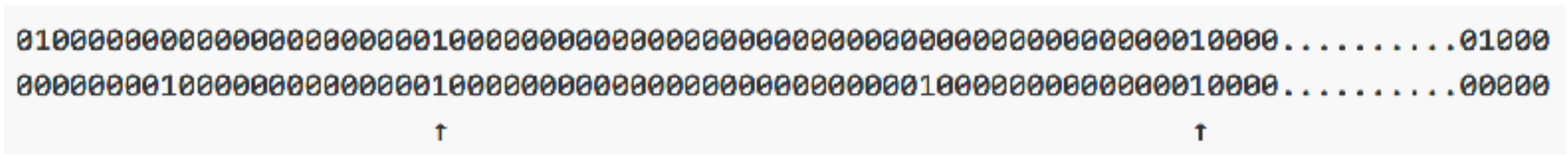
Sparse Distributed Representations

- SDRs are how brains solve the problem of knowledge
- Each bit has semantic meaning
- Extremely high capacity. For 2048 bit vector and 2% are set, we have >> 10^{84} unique patterns
- Randomly chosen patterns have minimum overlap



- Two representations with shared bits have some shared semantic information
- Comparing two representations is as simple as taking the intersection of the two indices sets.
- SDRs are inherently fault-tolerant and noise tolerant.
- Can check for existence of an SDR in a set by taking the union

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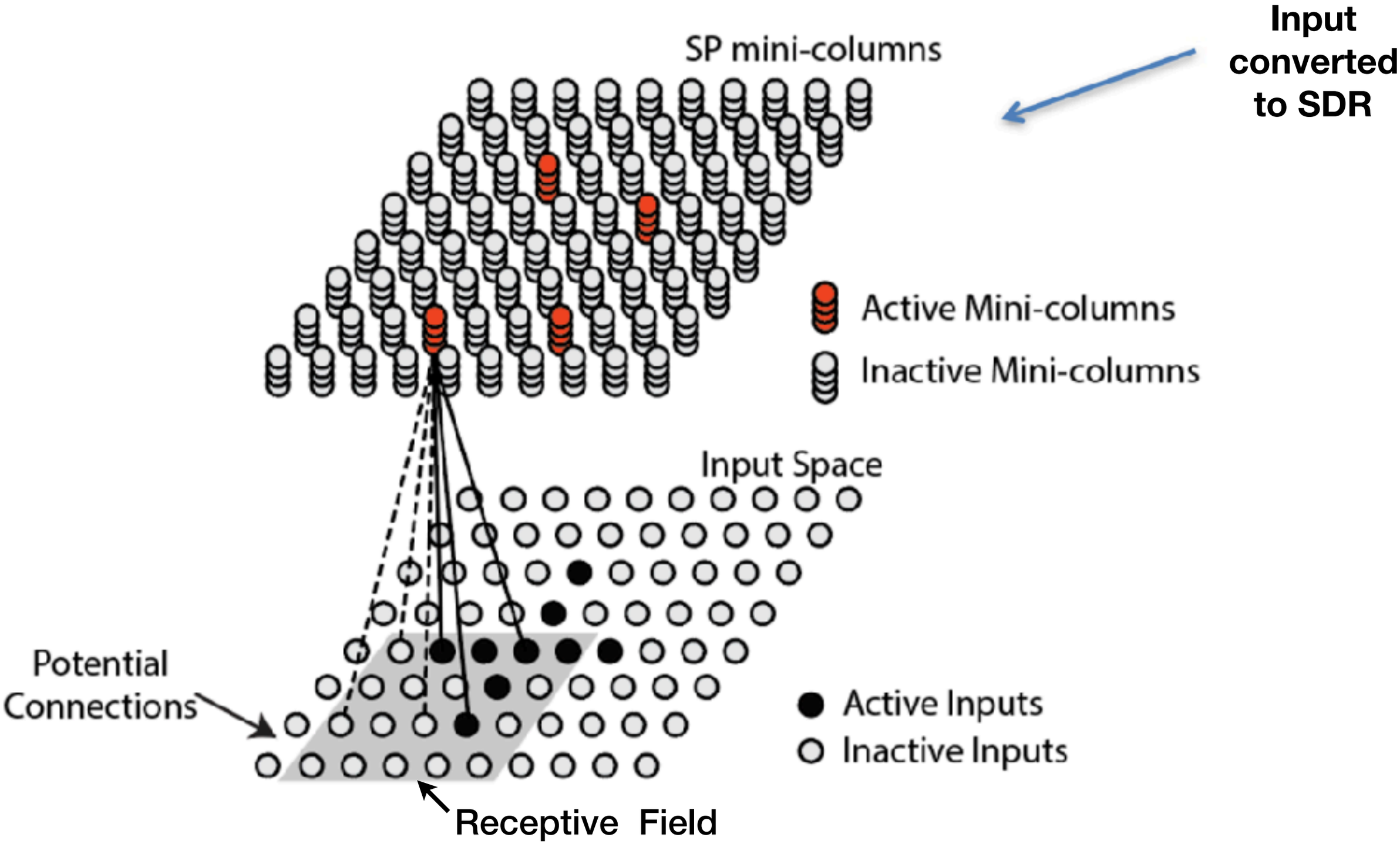
Create SDRs - Spacial Pooler



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Demo - Character Reader

ABCDEFGHIJKLM
NOPQRSTUVWXYZ
abcdefghijklm
nopqrstuvwxyz
1234567890

Chalkduster 0123456789

ABCDEFGHIJKLMNOPQRSTUVWXYZ

abcdefghijklmnopqrstuvwxyz

Courier New Bold Italic 0123456789

ABCDEFGHIJKLMNOPQRSTUVWXYZ

abcdefghijklmnopqrstuvwxyz

Times New Roman 0123456789

ABCDEFGHIJKLMNOPQRSTUVWXYZ

abcdefghijklmnopqrstuvwxyz

Comic Sans MS 0123456789

ABCDEFGHIJKLMNOPQRSTUVWXYZ abcdefghijklmnopqrstuvwxyz

HERCULANUM 0123456789

ABCDEFGHIJKLMNOPQRSTUVWXYZ

ABCDEFGHIJKLMNOPQRSTUVWXYZ

Xingkai 0123456789

ABCDEFGHIJKLMNOPQRSTUVWXYZ

abcdefghijklmnopqrstuvwxyz

SnellRoundhand 0123456789

ABCDEFGHIJKLMNOPQRSTUVWXYZ

abcdefghijklmnopqrstuvwxyz

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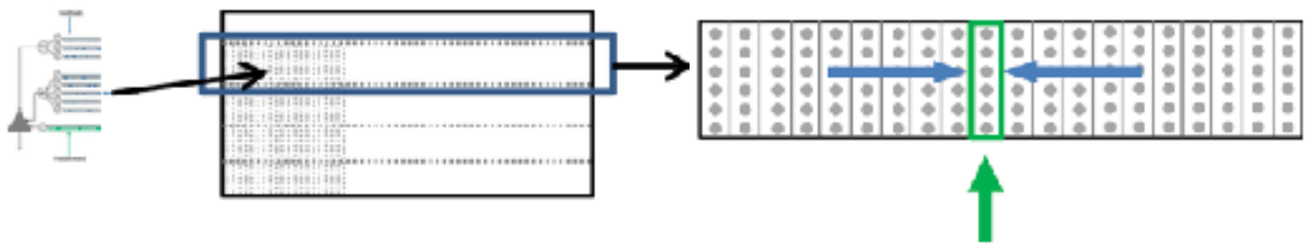
Temporal (or Sequence) Memory



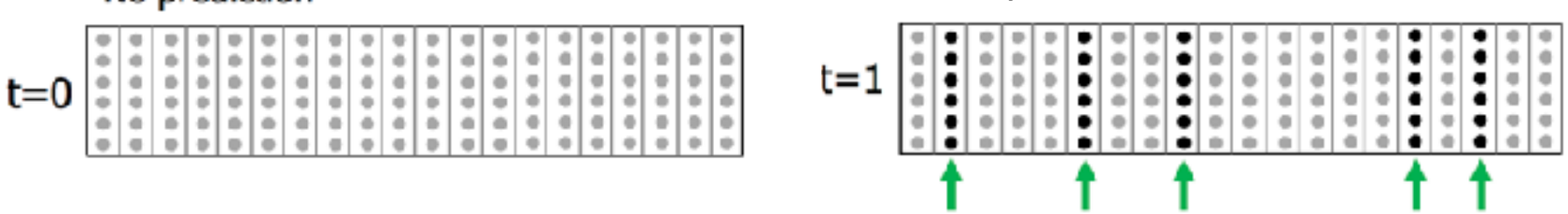
- Neurons in a mini-column learn same FF receptive field.
- Neurons forms distal connections to nearby cells.

Before

No prediction

Feedforward input

Time ⟶

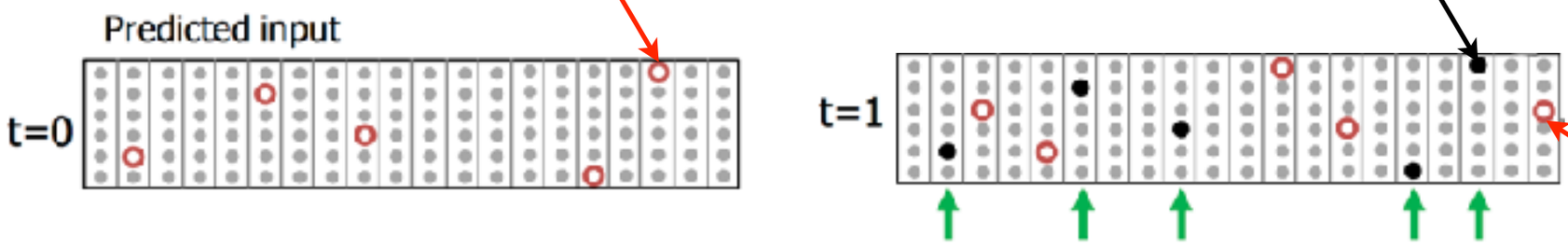


Predicted

Predicted cells fire first and inhibit

After

Predicted input



Next predicted cell when

- Makes predictions of what the next input SDR will be
- Huge capacity (can learn more than 1 million transitions)
- Learns higher order sequences: “ABCD” vs “XBCY”
- Makes simultaneous predictions: “..BC” predicts “D” and “Y”
- Extremely robust (40% noise and fault tolerant)
- Learning is unsupervised, continuous and local

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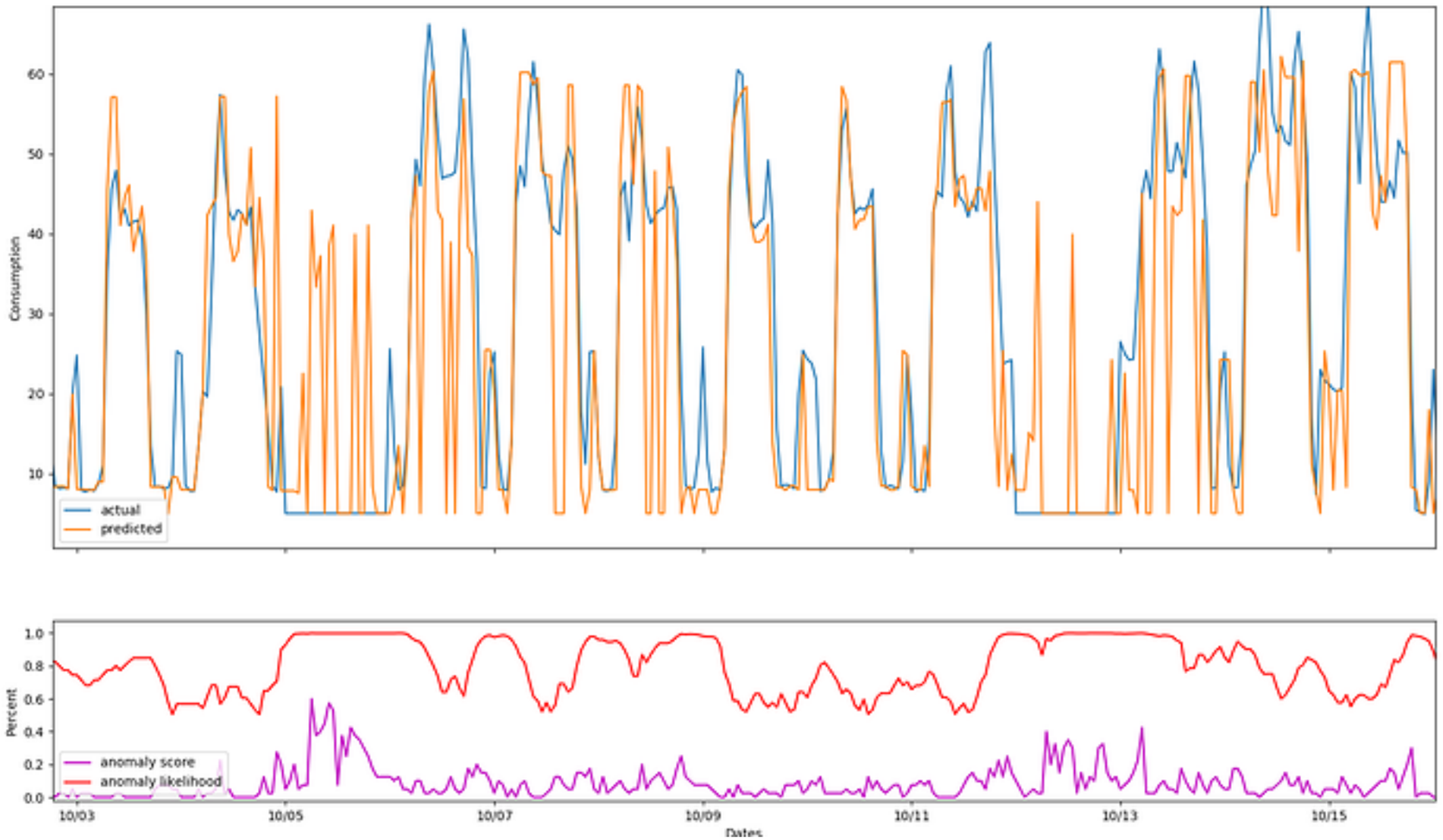
Demo - Anomaly Detection



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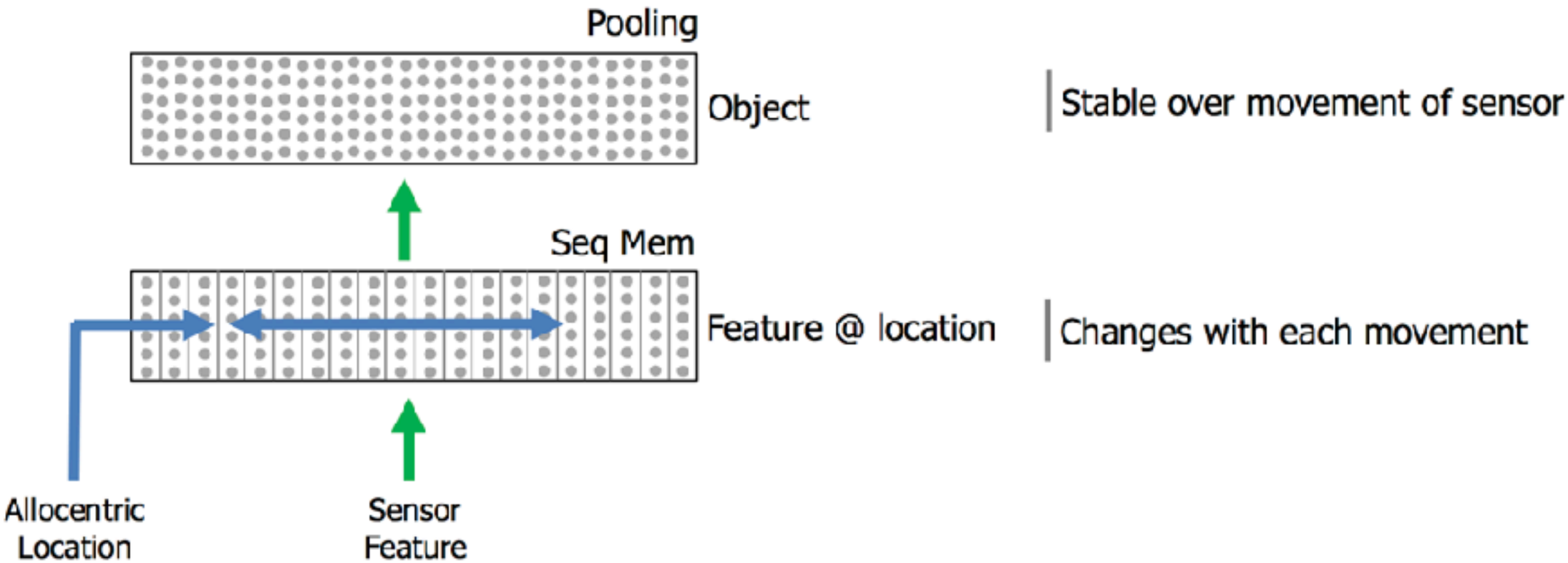
Sensorimotor Sequence Memory



- Such a column can learn models of complete objects by sensing different locations on an object over time

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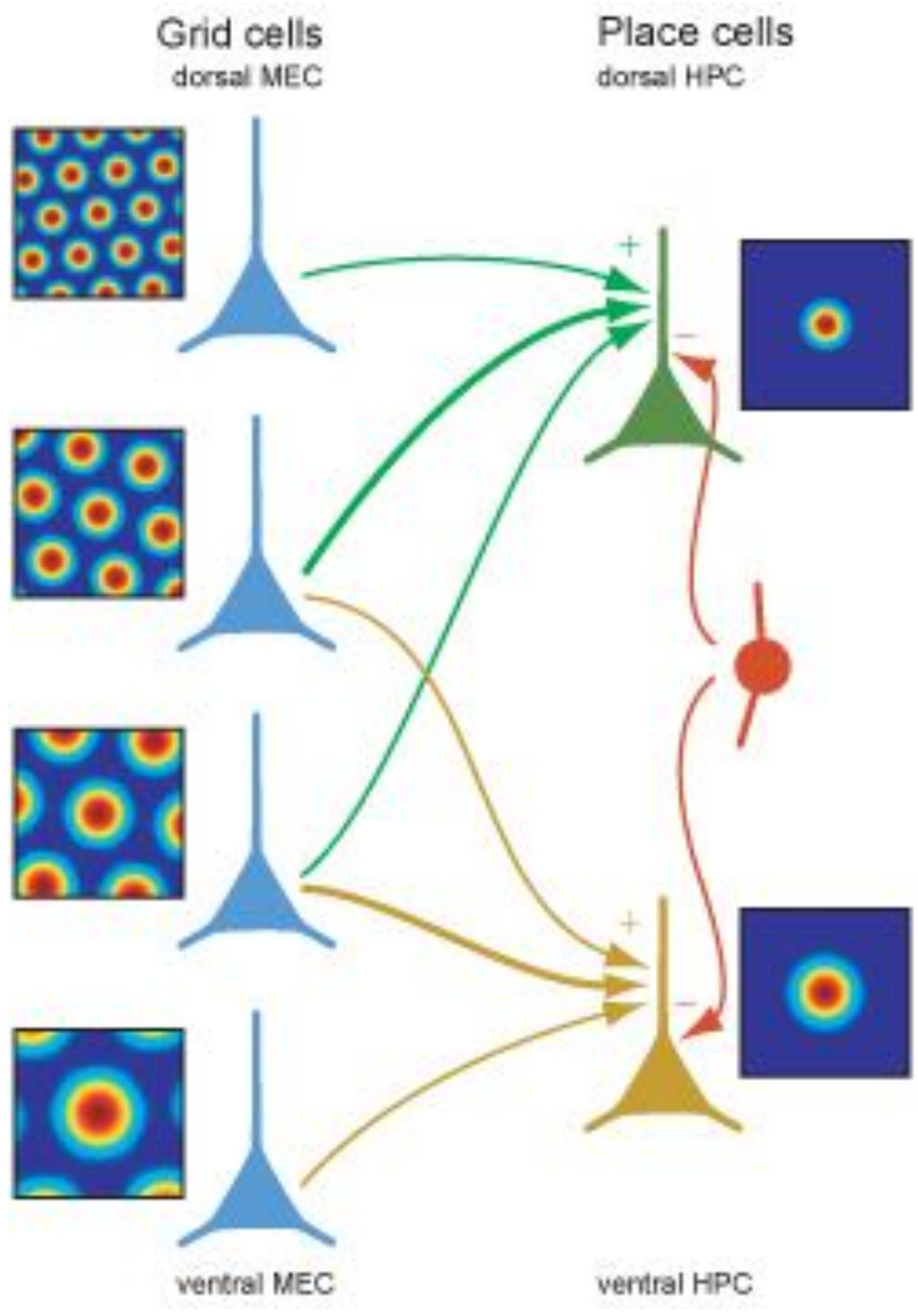
Grid and Place Cells



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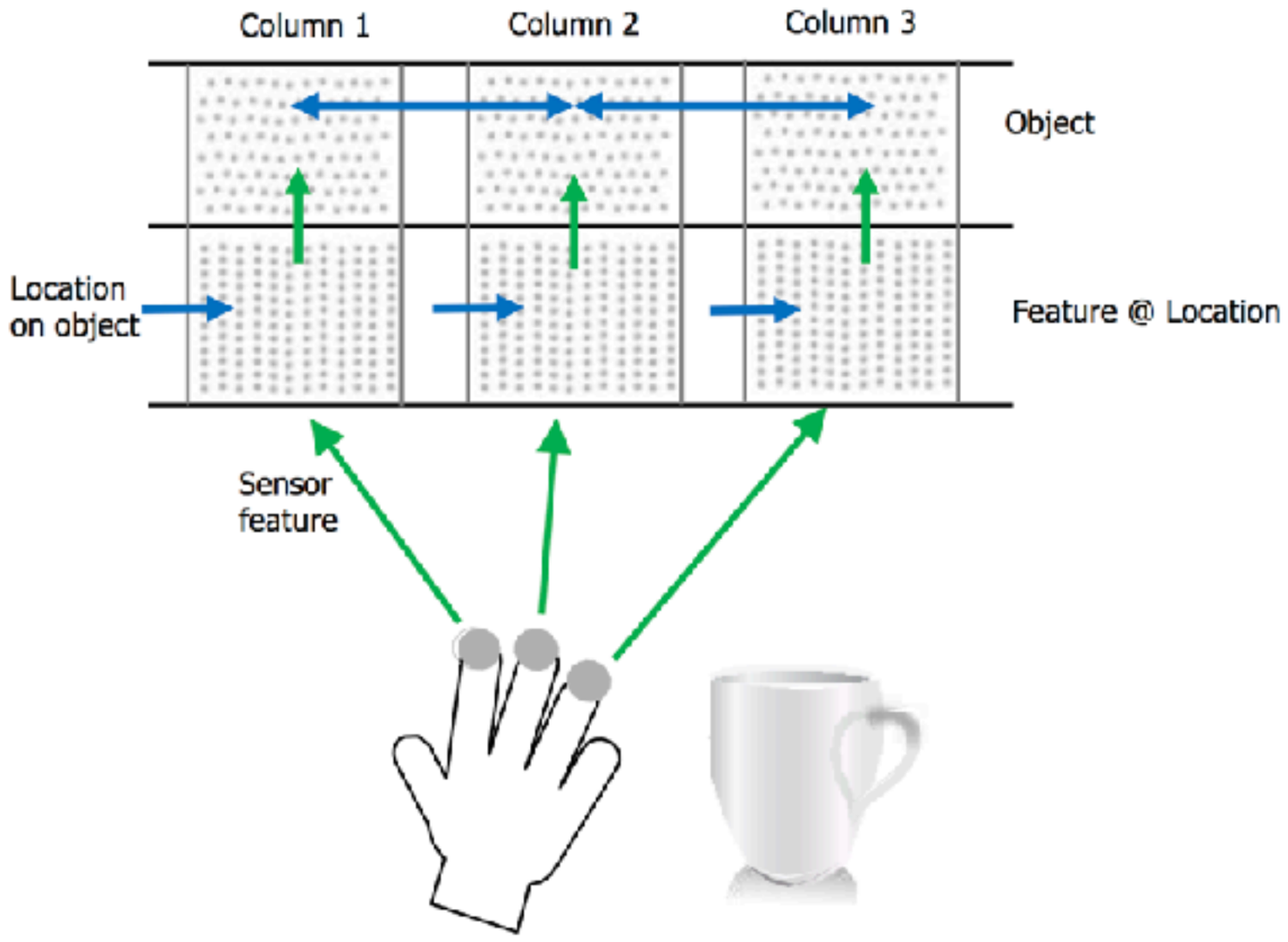
Sensorimotor with Multiple Columns



- Each column has partial knowledge of the object
- Long range connections in object layer allow columns to vote
- Inference is faster

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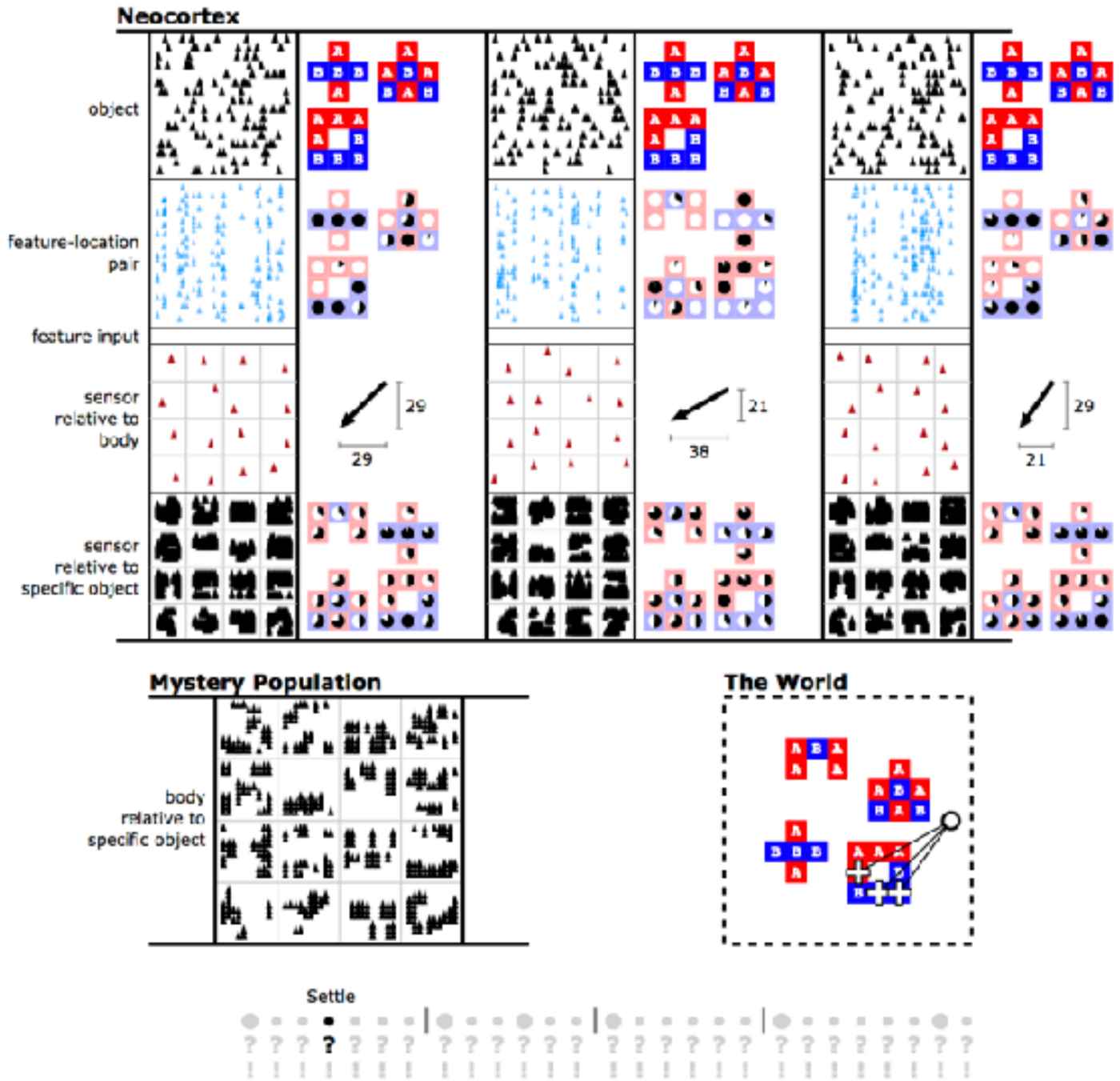
Demo - Sensorimotor



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Commercial Applications

http://grokstream.com/

http://www.cortical.io/

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Links

- https://numenta.com/

- https://numenta.org/

- HTM School: https://www.youtube.com/channel/UC8-ttzWLgXZOGuhUyrPlUuA

Slides and Demos

- https://github.com/fcr/python_meetup_htm_slides

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Questions?

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