Brains
Data
Machine Intelligence

Fujitsu
North America Technology Forum

Jeff Hawkins
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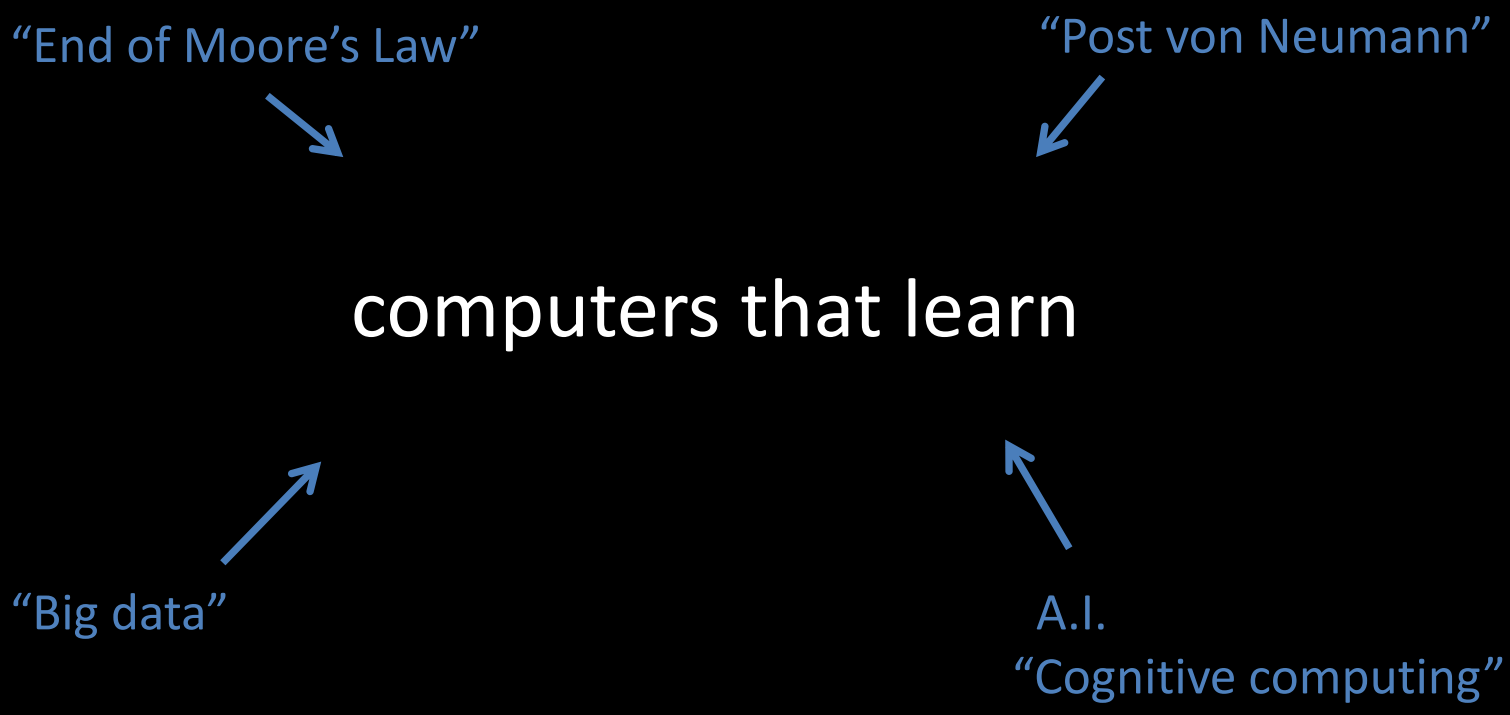
GROK Numenta

“If you invent a breakthrough so computers can learn, that is worth 10 Microsofts”

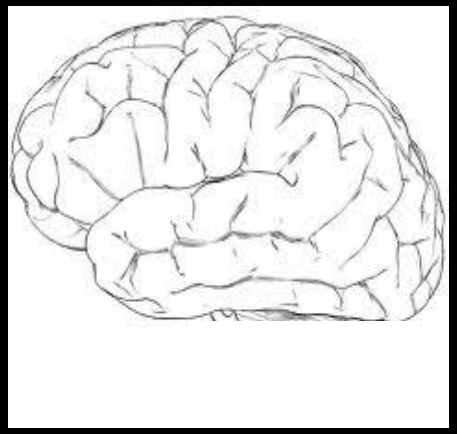

“End of Moore’s Law”
“Post von Neumann”
computers that learn
“Big data”
A.I.
“Cognitive computing”

Machine Intelligence

computers that learn

1) What principles will we use to build intelligent machines?

2) What applications will drive adoption in the near and long term?



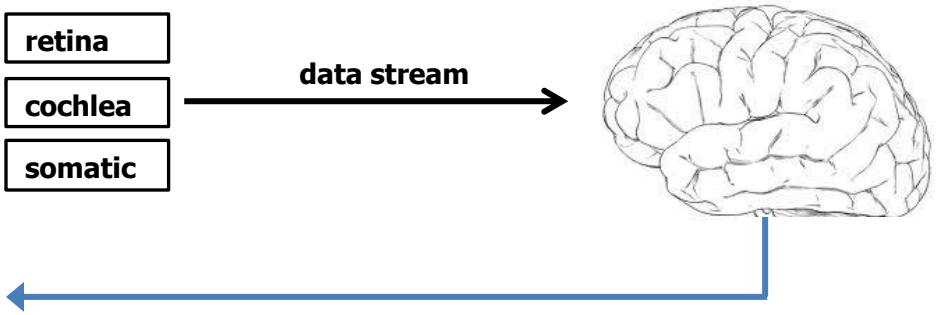
Machine intelligence will be built on the principles of the neocortex

1) Flexible (universal learning machine)

2) Robust

3) If we knew how the neocortex worked, we would be in a race to build them.

The neocortex is a learning system



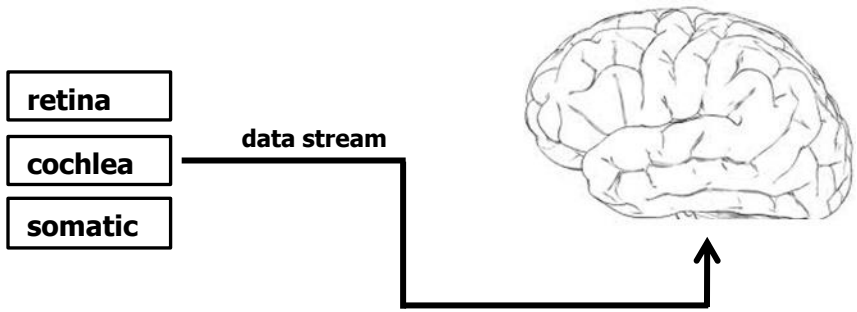
The neocortex learns a model from sensory data

- predictions
- anomalies
- actions

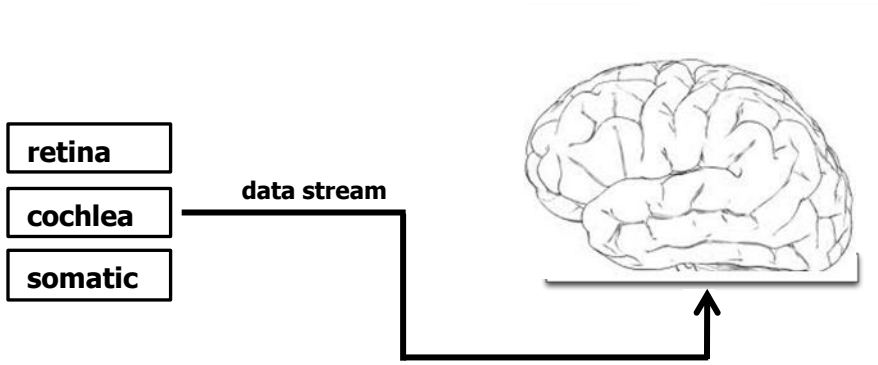
The neocortex learns a sensory-motor model of the world

Principles of Neocortical Function

1) On-line learning from streaming data



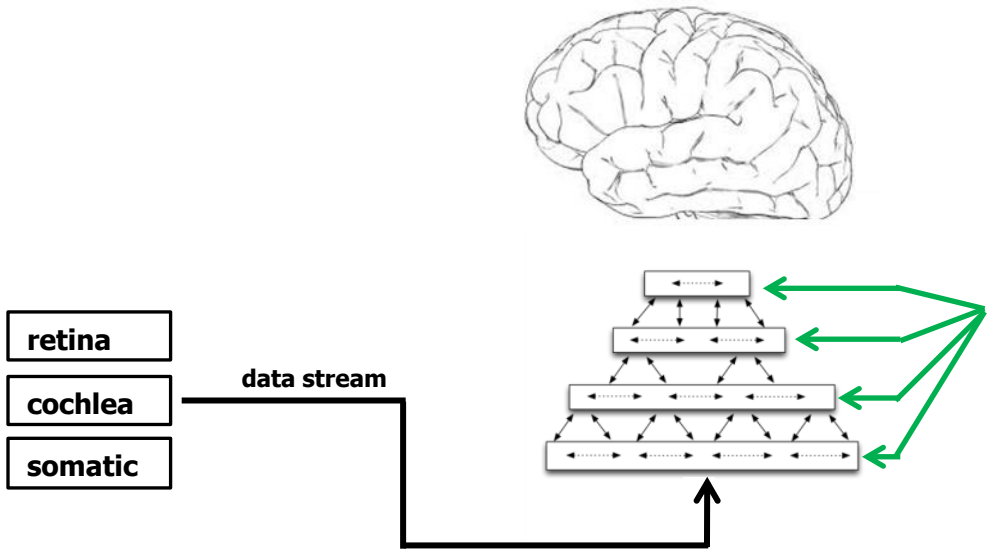
Principles of Neocortical Function



1) On-line learning from streaming data

2) Hierarchy of memory regions

Principles of Neocortical Function

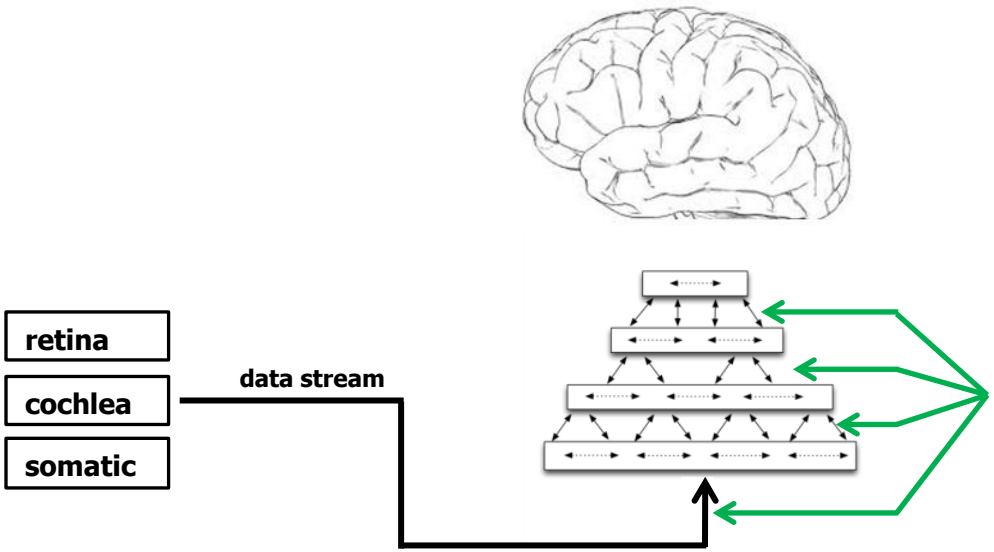


1) On-line learning from streaming data

2) Hierarchy of memory regions

3) Sequence memory
   - inference
   - motor

Principles of Neocortical Function



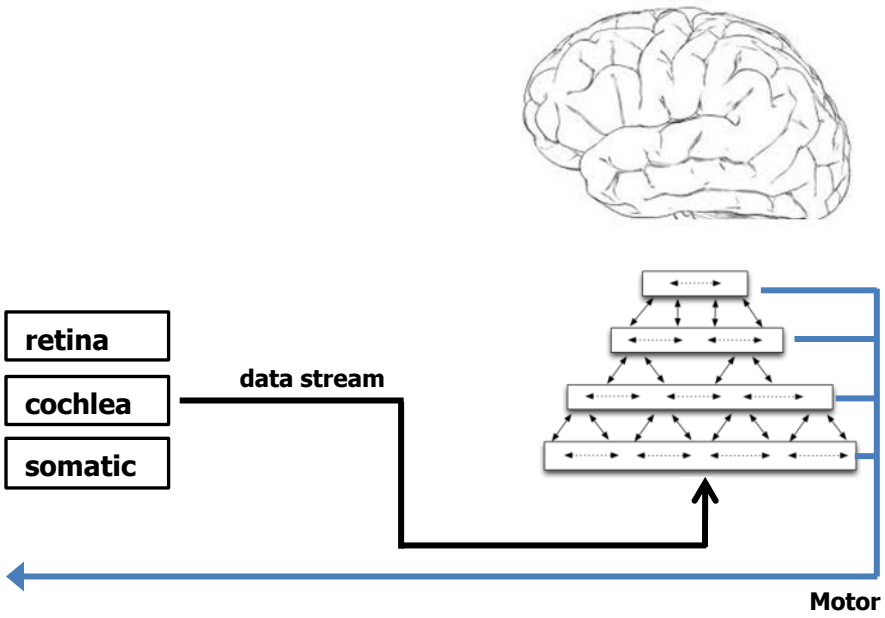
1) On-line learning from streaming data

2) Hierarchy of memory regions

3) Sequence memory

4) Sparse Distributed Representations

Principles of Neocortical Function



1) On-line learning from streaming data

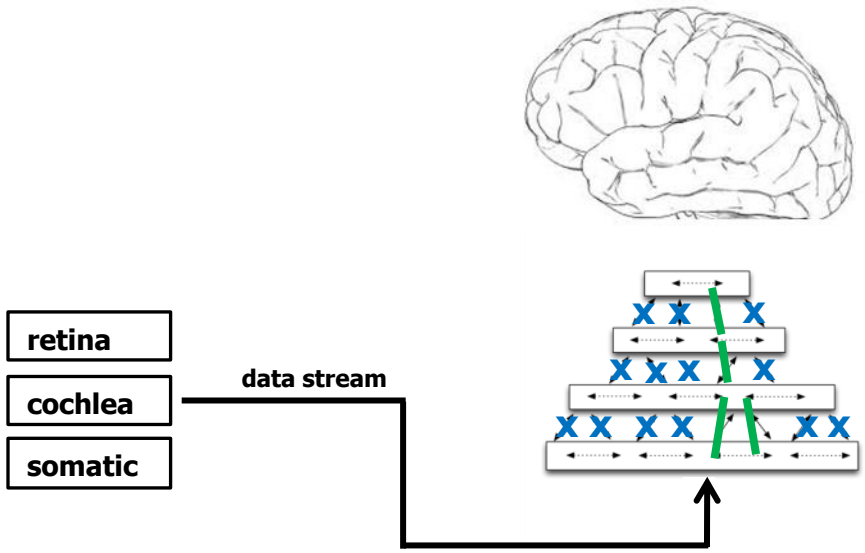
2) Hierarchy of memory regions

3) Sequence memory

4) Sparse Distributed Representations

5) All regions are sensory and motor

Principles of Neocortical Function



1) On-line learning from streaming data

2) Hierarchy of memory regions

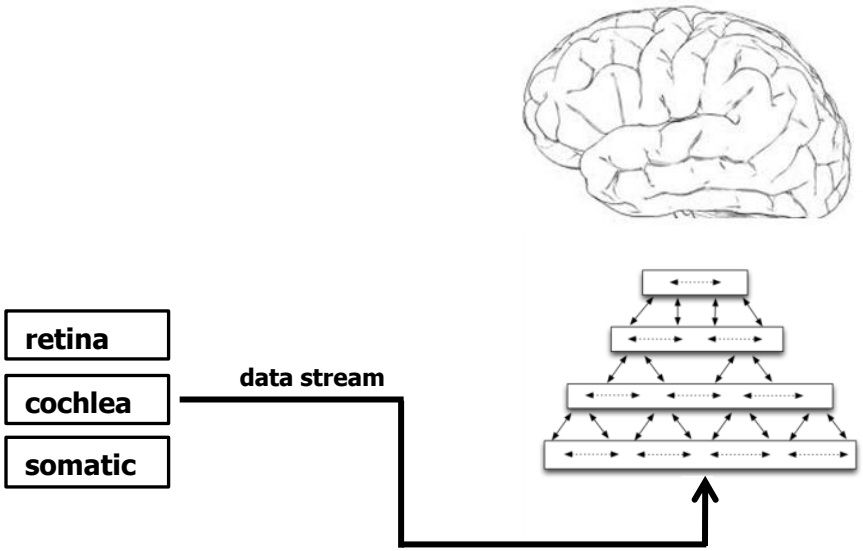
3) Sequence memory

4) Sparse Distributed Representations

5) All regions are sensory and motor

6) Attention

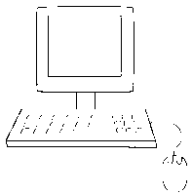
Principles of Neocortical Function



1) On-line learning from streaming data
2) Hierarchy of memory regions
3) Sequence memory
4) Sparse Distributed Representations
5) All regions are sensory and motor
6) Attention

These six principles are necessary and sufficient for biological and machine intelligence.

Dense Representations



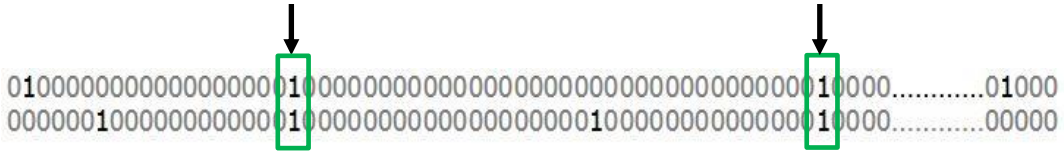
- Few bits (8 to 128)
- All combinations of 1's and 0's
- Example: 8 bit ASCII
  01101101 = m
- Individual bits have no inherent meaning
- Representation is assigned by programmer

Sparse Distributed Representations (SDRs)

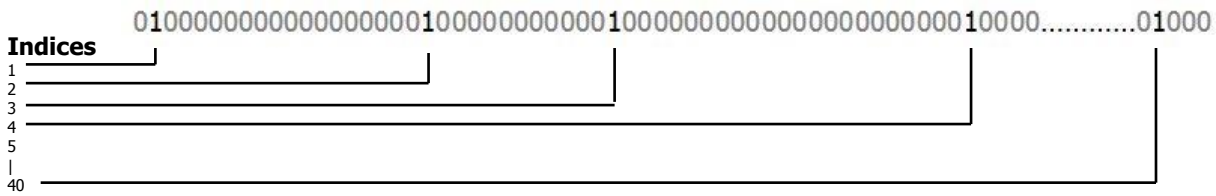
- Many bits (thousands)
- Few 1's mostly 0's
- Example: 2,000 bits, 2% active
  0100000000000000001000000000000000000000000000000010000.....01000
- Each bit has semantic meaning
- Meaning of each bit is learned, not assigned

SDR Properties

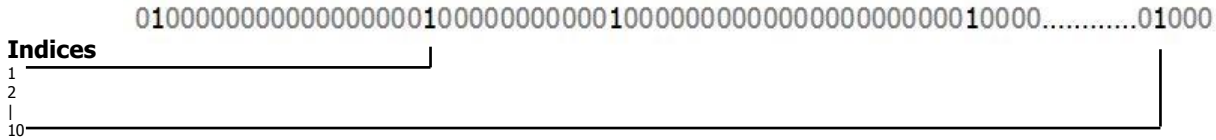
1) **Similarity**:
shared bits = semantic similarity



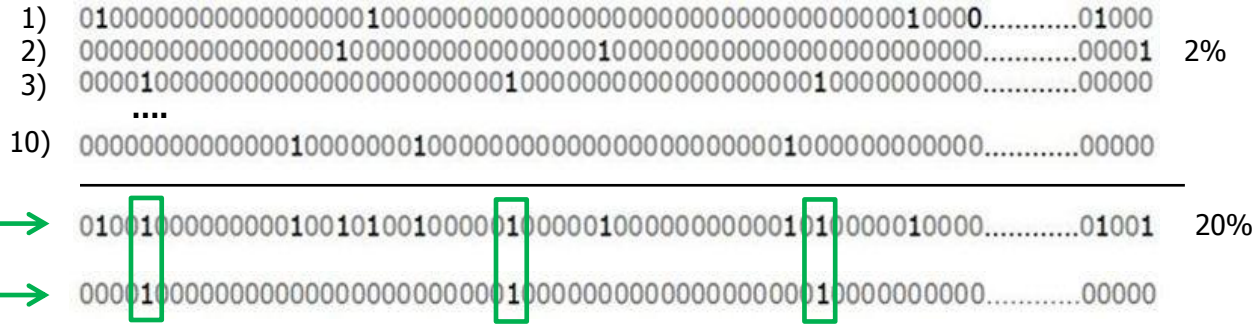
2) **Store and Compare**:
store indices of active bits



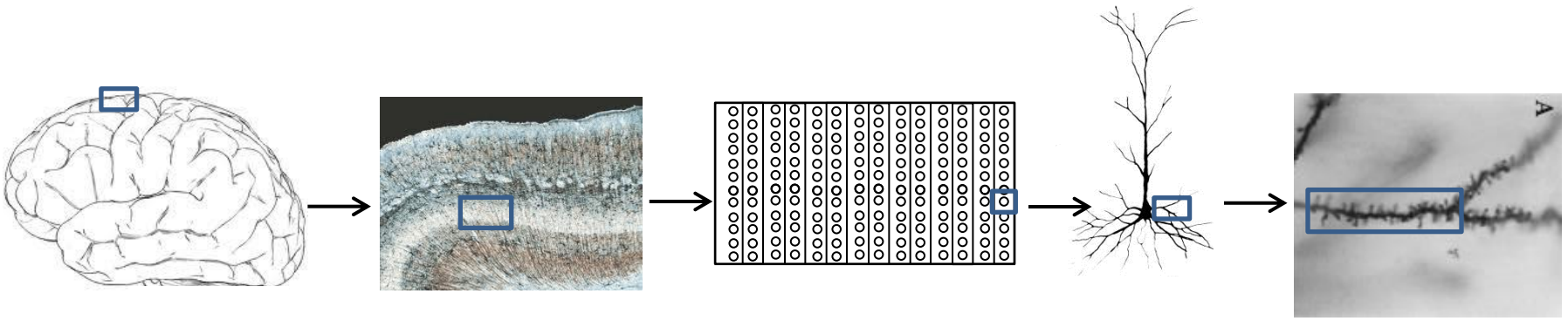
subsampling is OK

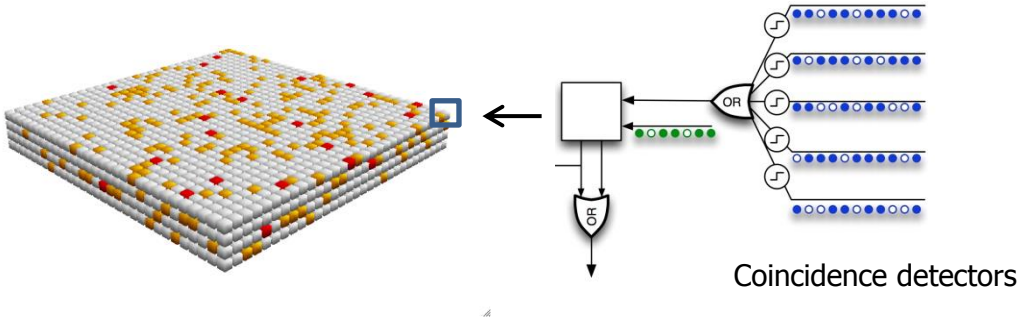


3) **Union membership**:



Sequence Memory

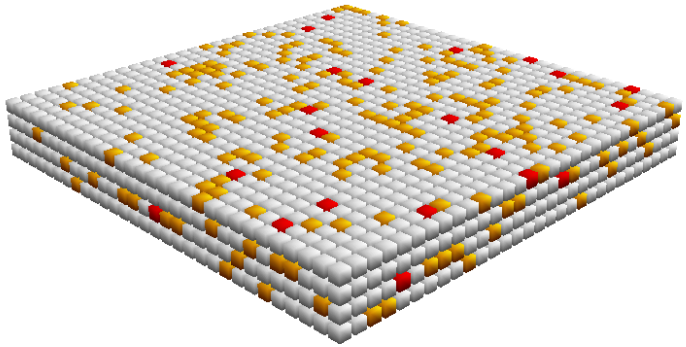




Coincidence detectors

Cortical Learning Algorithm (CLA)

Converts input to SDRs
Learns sequences of SDRs
Makes predictions and detects anomalies

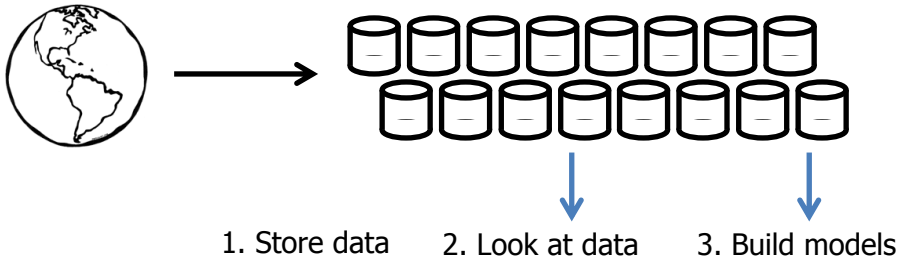


- High order sequences
- On-line learning
- High capacity
- Multiple predictions
- Fault tolerant

Basic building block of neocortex/Machine Intelligence

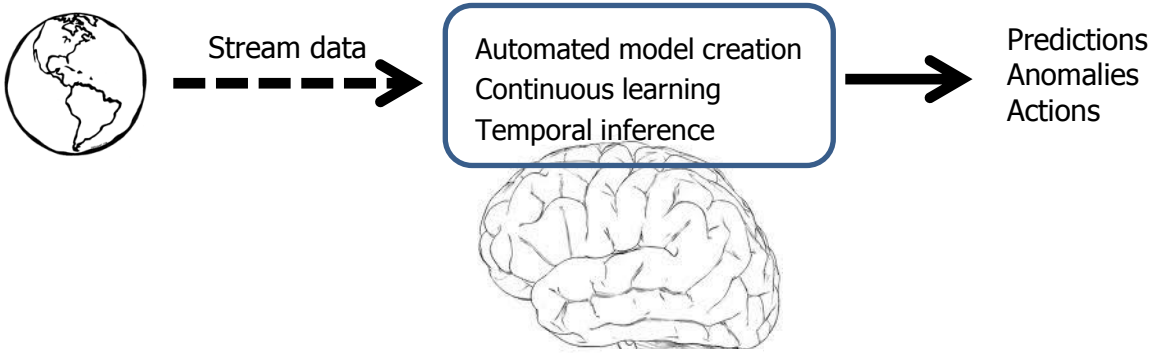
Application: Anomaly detection in data streams

Past

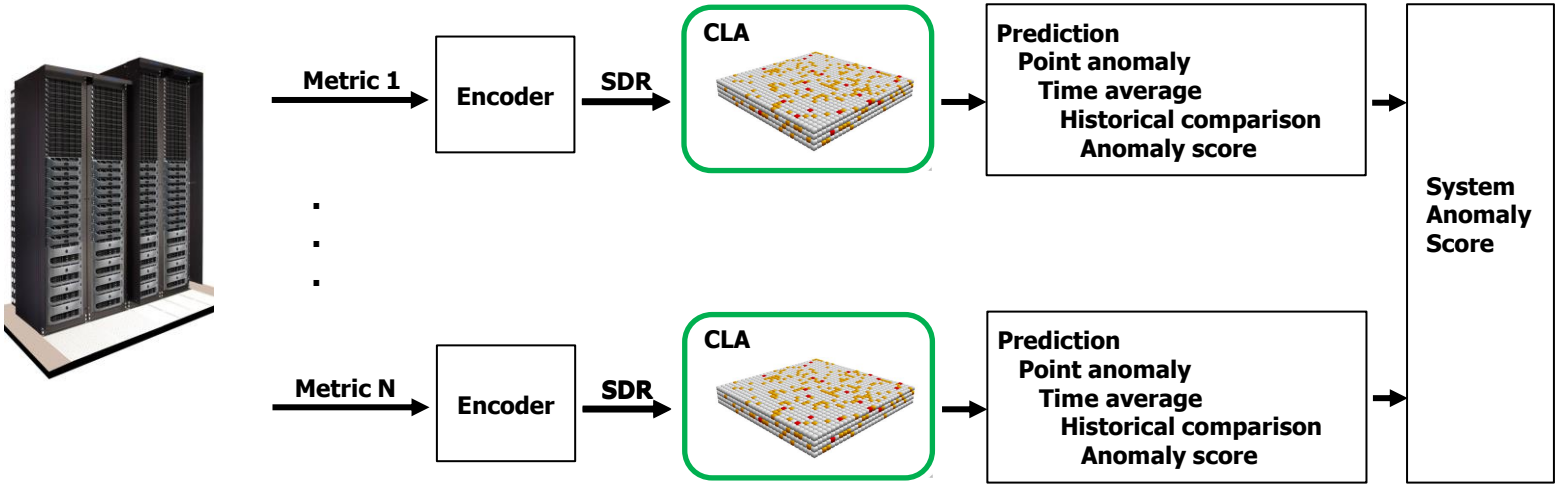


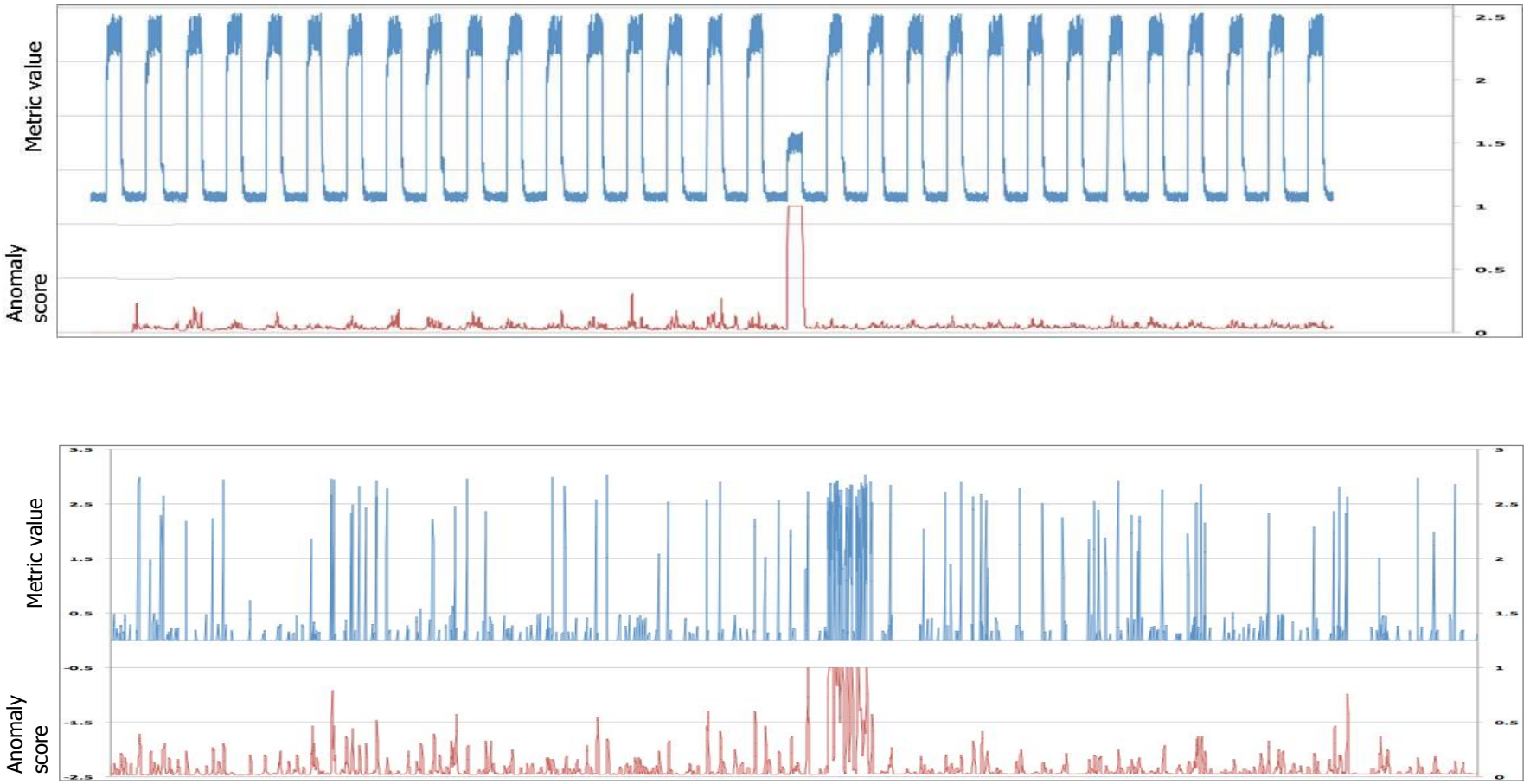
Problem: - Doesn't scale with velocity and # of models

Future

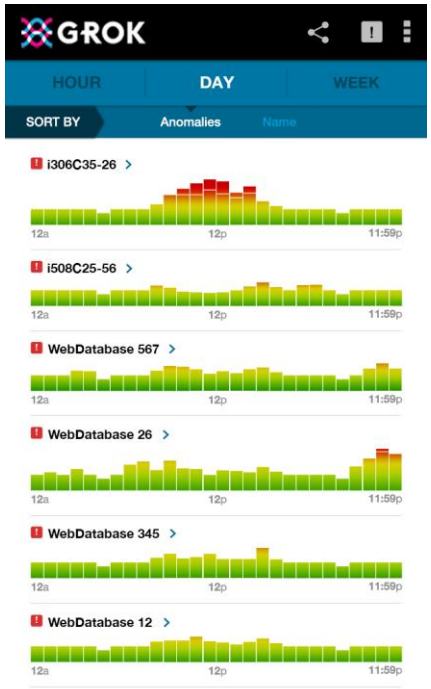


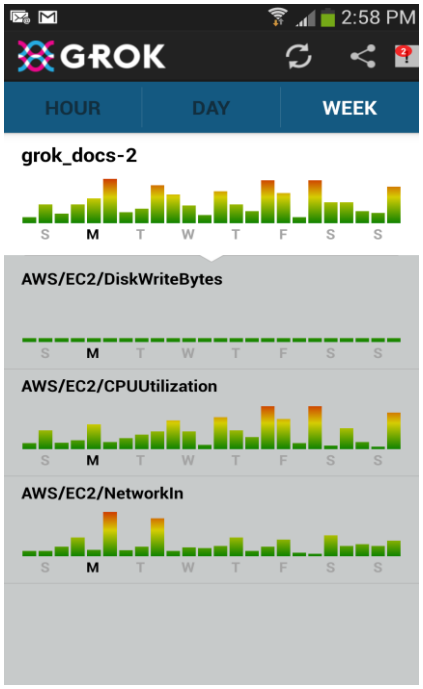
Anomaly Detection Using Cortical Principles

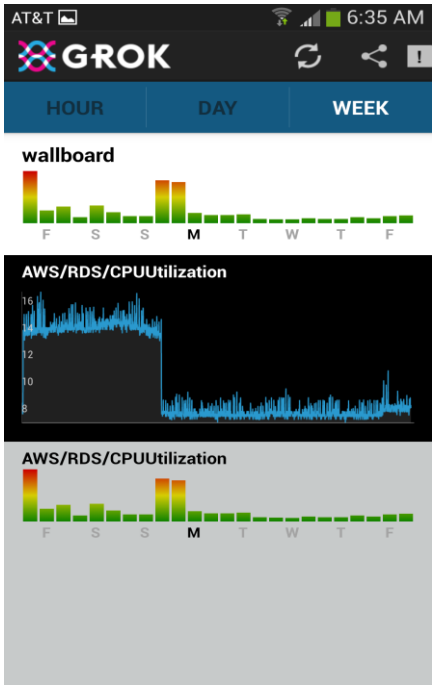



Metric value
Anomaly score
2.5
2
1.5
1
0.5
0
Metric value
Anomaly score
3.5
2.5
1.5
0.5
-0.5
-1.5
-2.5
3
2.5
2
1.5
1
0.5
0

Grok for Amazon AWS
"Breakthrough Science for Anomaly Detection"



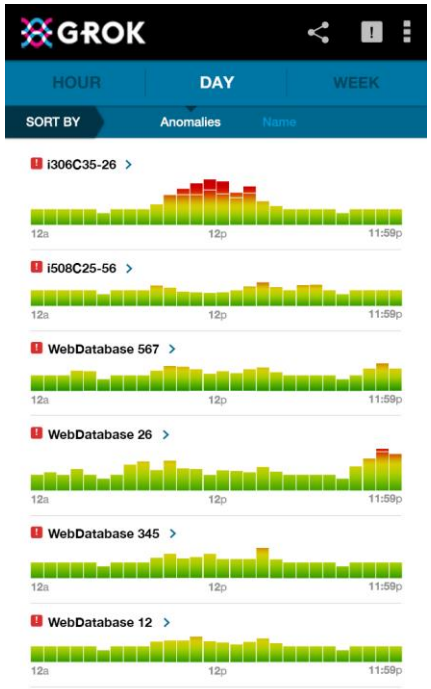


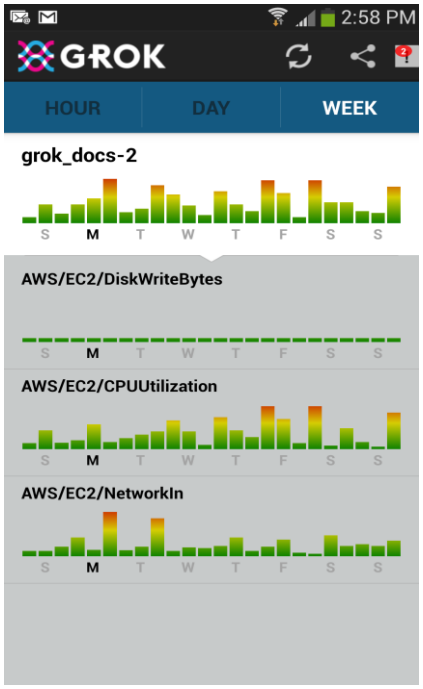


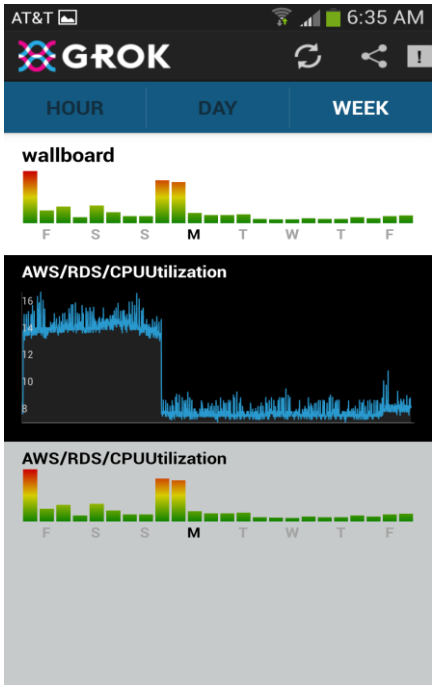
- **Ranks anomalous instances**
- **Monitor 100's of instances via smartphone**
- **Continuously updated**
- **Continuous learning**
- **Automated model creation**

Grok for Amazon AWS

"Breakthrough Science for Anomaly Detection"



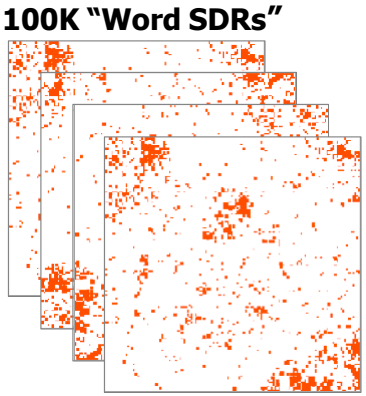




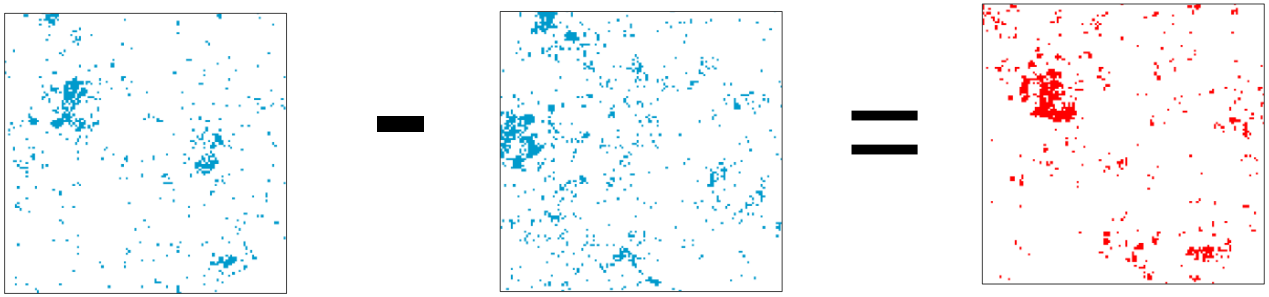
Grok technology can be applied to any kind of data financial, manufacturing, web sales, etc.

Application: CEPT Systems

Document corpus
(e.g. Wikipedia)



Apple − **Fruit** = **Computer**



Macintosh
Microsoft
Mac
Linux
Operating system
....

Sequences of Word SDRs

Training set

frog	eats	flies
cow	eats	grain
elephant	eats	leaves
goat	eats	grass
wolf	eats	rabbit
cat	likes	ball
elephant	likes	water
sheep	eats	grass
cat	eats	salmon
wolf	eats	mice
lion	eats	cow
dog	likes	sleep
elephant	likes	water
cat	likes	ball
coyote	eats	rodent
coyote	eats	rabbit
wolf	eats	squirrel
dog	likes	sleep
cat	likes	ball
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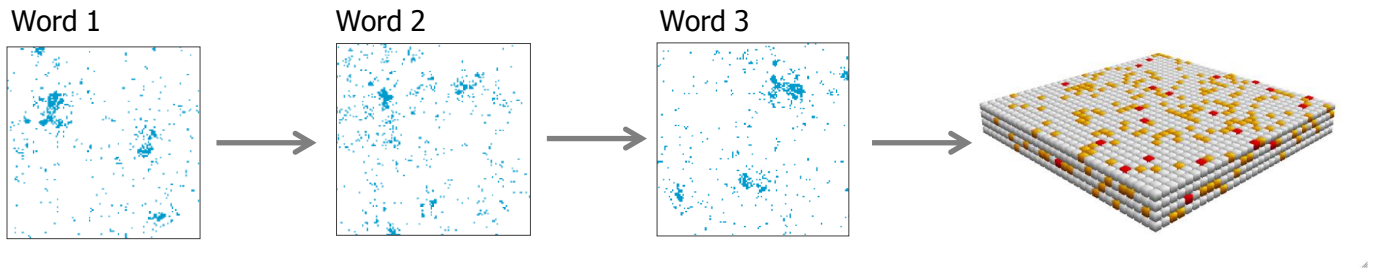

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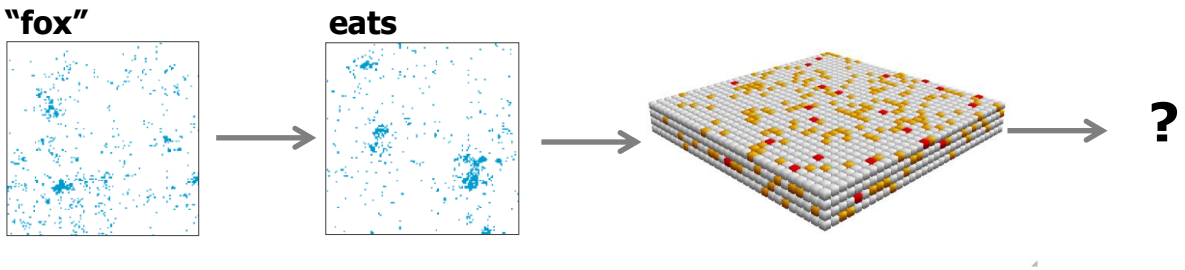

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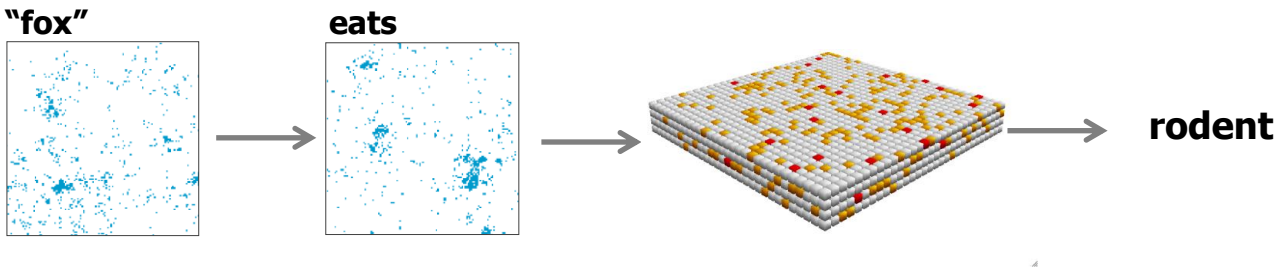


1) Word SDRs created unsupervised

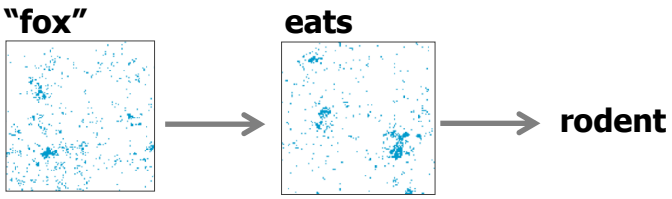
2) Semantic generalization

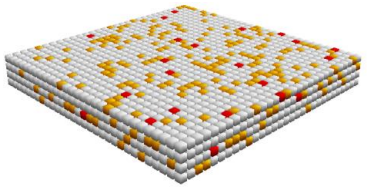
SDR: lexical
CLA: grammatic

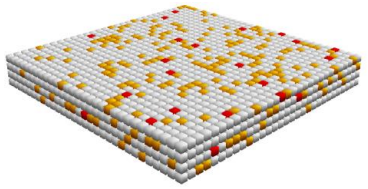
3) Commercial applications

Sentiment analysis
Abstraction
Improved text to speech
Dialog, Reporting, etc.
www.Cept.at

Cept and Grok use exact same code base







NuPIC Open Source Project

(Numenta Platform for Intelligent Computing)

Source code for:

- Cortical Learning Algorithm
- Encoders
- Support libraries

Single source tree (used by GROK), GPLV3

Active and growing community

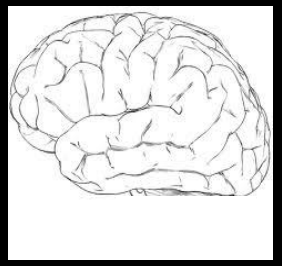
- 73 contributors
- 311 mailing list subscribers
- **IBM, Darpa**

Hackathons

Education Resources

www.Numenta.org

Numenta



1) The neocortex is as close to a universal learning machine as we can imagine

2) Machine intelligence will be built on the principles of the neocortex

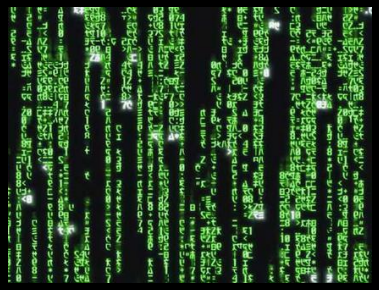
3) Six basic principles
   SDRs, sequence memory, on-line learning hierarchy, sensorimotor, attention

4) CLA is a building block

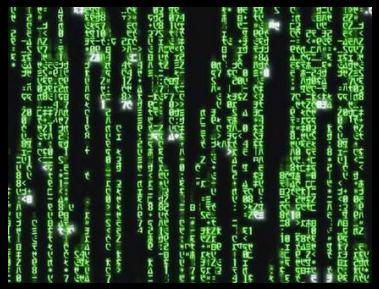
5) Near term applications
   language, anomaly detection, robotics

6) Participate www.numenta.org

Future of Machine Intelligence



Future of Machine Intelligence



Definite

- Faster, Bigger
- Super senses
- Fluid robotics
- Distributed hierarchy

Maybe

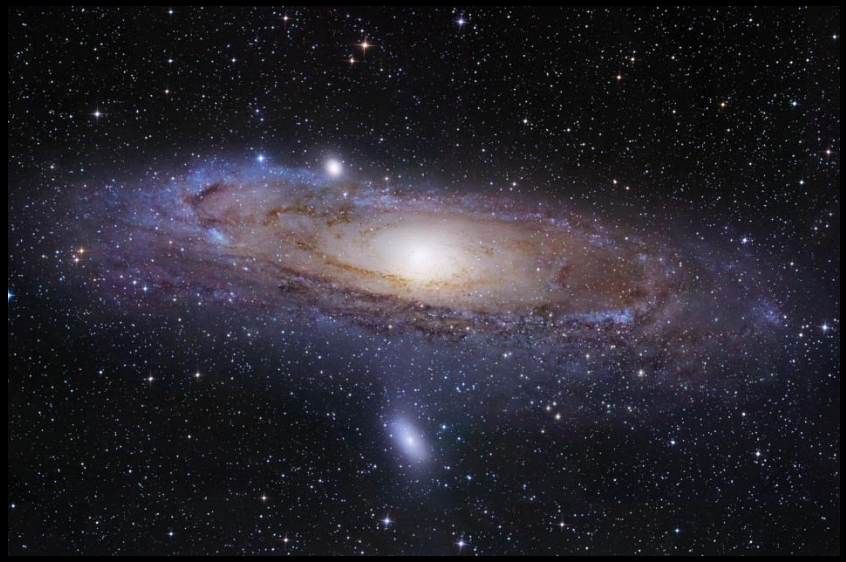
- Humanoid robots
- Computer/Brain interfaces for all

Not

- Uploaded brains
- Evil robots

Why Create Intelligent Machines?

Live better



Learn more

Thank You