The IBM Machine Intelligence Project
- Overview (Wilcke) and Neural Model (Ozcan)

NICE V March 2017
@ IBM Research, San Jose CA
Vision for Machine Intelligence Project (MI)

- Machines which will use fast associative reasoning to mimic human intelligence

- Machine Intelligence (MI) operates very differently than Machine Learning (ML)
  - We use the MI/ML terminology of Jeff Hawkins (Numenta)
Four interrelated Research Areas

- Biological & Neural Model Definition (2nd half of this talk)
- Context Aware Learning (CAL) – Algorithms and Software
- Escape 9000 ‘Neural Supercomputer’
- Roving Robots (KATE & Turtle-Bot)
Key Concepts of Machine Intelligence Project

- Closely guided by neuroscience – not just “inspired”
- Unsupervised & continuous learning
  - via autonomous detection & prediction of spatio-temporal noisy patterns
- Autonomously build ‘world models’
  - realize the model as hierarchies of Sparse Distributed Representations - SDR
    - 0000000000001000000010100000000000000000100000000000001000
  - roving robots to get the data for building the world model
- Learning is mostly due to formation of new synapses (plastic topology)
- Feedback is very important
Neocortex

Layer 1
Layer 2/3
Layer 4
Layer 5
Layer 6

Mini-Column

One Neuron
Simple Neural Hierarchy

**INPUTS:**
Spatial-temporal data streams of any kind

**OUTPUTS:**
- Predictions
- Contexts
- Stable Concepts
- Motor commands

Sparse Distributed Pattern ("Representation") of firing neurons
SDR=SDR(time)

Array of columns of neurons aka "Sequence Memory" (J.Hawkins et.al.)
Layers, Levels and Regions

- **Regions** are stacks of 5 neural “Layers”
- Multiple Regions form a “Level”
- Multiple Levels form a “Tree” (or other topology)
- System is a collection of these Trees
  – but see next slides
Thalamus – two important Functions

- Central router for:
  - communication between
    - regions to regions and to sensors & motors
    - local neural hierarchies
  - feedback between regions

- Blackboard for sharing data between regions
Feedback through the Thalamus

Thalamus metaphors:
"Active blackboard" David Mumford (1991, 1992)
"Blackboard" Newman and Baars (1993)
The Importance of Feedback

Text stream, with errors inserted

Absolute error in ASCII prediction

Time
Current Status…
Baby CAL

- 2 regions on 2 levels
- sufficient to test key functions of CAL

Region R2 on Level 2

- (L1) Process feedback
- (L2/3) Sequence memory
- (L4) Pooler & correlator
- (L5) Thalamic output
- L6 Attention – pending

Region R1 on Level 1

- (L1) Process feedback
- (L2/3) Sequence memory
- (L4) Pooler & correlator
- (L5) Thalamic output
- L6 Attention – pending

Green lines: Feedback

Red lines: Feed-forward

Encoded (sensor) input

Via (software implemented) thalamus
(Baby) CAL in four Video Demos (outside)

- ‘Correlator’ Video
  - Dynamic formation of synapses connecting neurons which are firing simultaneously due to correlated inputs

- ‘Sequence Memory’ Video
  - Prediction of phase-space behavior of a chaotic oscillator

- ‘Temporal Pooler’ Video
  - Streaming text and persistent SDR(time) in upper Level 2

- ‘Feedback’ Video
  - Streaming text, randomly damaged, is better predicted with feedback between Levels
ESCAPE 9000

• The brain is an extremely connected system of strongly non-linear elements
  • There is no closed-form mathematics for such systems
  • Tens of thousands of numerical experiments required
  • Model plastic topology as software structures

• We are building a new supercomputer for these experiments – ESCAPE 9000
  • Very flexible and fast (1296 FPGA + 2592 ARM cores)
  • Very high bandwidth, TB of RAM
  • Scalable to even larger sizes and waferscale (SHANNON)

• Already running CAL (see demo outside)
Robots for Machine Intelligence

- **We are building robots for several reasons**
  - Demonstrate unsupervised learning
  - Build a world model
  - Gain experience with the sensory-motor loop

- **Unsupervised Learning**
  - Our two-legged robots have learned—on their own—to detect sensory anomalies and react to prevent falling
  - 1900 steps without falling

- **World Model (future)**
  - Use roving robots to learn facts about the world

Anomaly Detection while walking
The Path to Reasoning

1. Describe the world as billions of SDR’s in a neocortical forest of neural ‘trees’ plus the Thalamus structure

2. Exploit the semantic properties of SDR and the power of ESCAPE 9000 to quickly find associations, i.e. overlaps between SDRs
   – If it walks like a duck and looks like a duck and quacks like duck it probably is a duck!
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Thank you!