# 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)

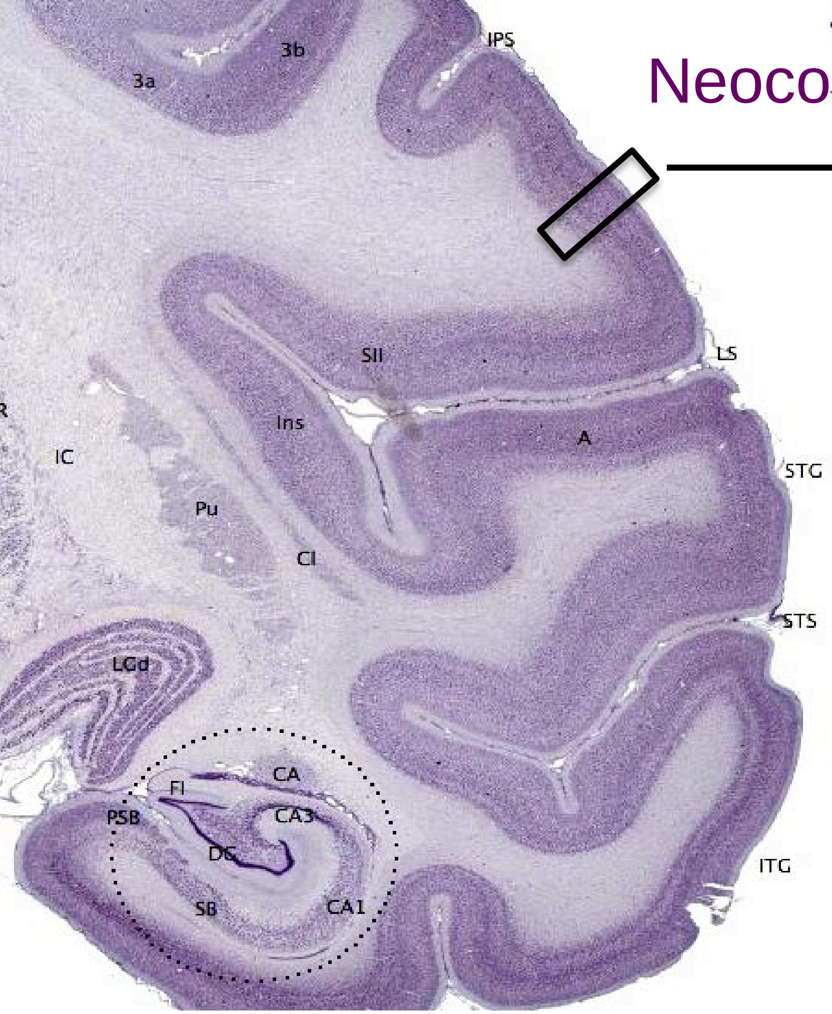
# Four interrelated Research Areas

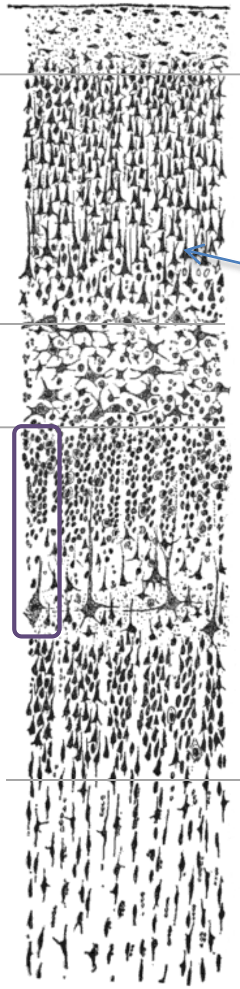
- **Biological & Neural Model Definition (2nd half of this talk)**
- **Context Aware Learning (CAL) – Algorithms and Software**
- **Escape 9000 ‘Neural Supercomputer’**
- **Roving Robots (KATE & Turtle-Bot)**

# 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
    - 000000000000010000000101000000000000000000100000000000000001000
  - roving robots to get the data for building the world model
- **Learning is mostly due to formation of <u>new</u> synapses (plastic topology)**
- **Feedback is <u>very</u> important**

# Neocortex



Mini-Column

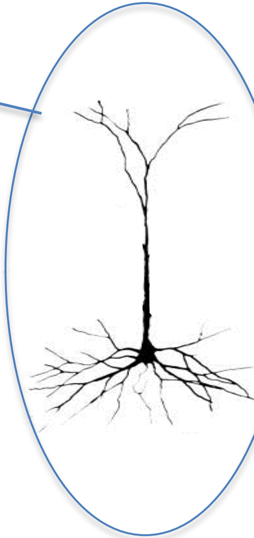
Layer 1

Layer 2/3

Layer 4

Layer 5

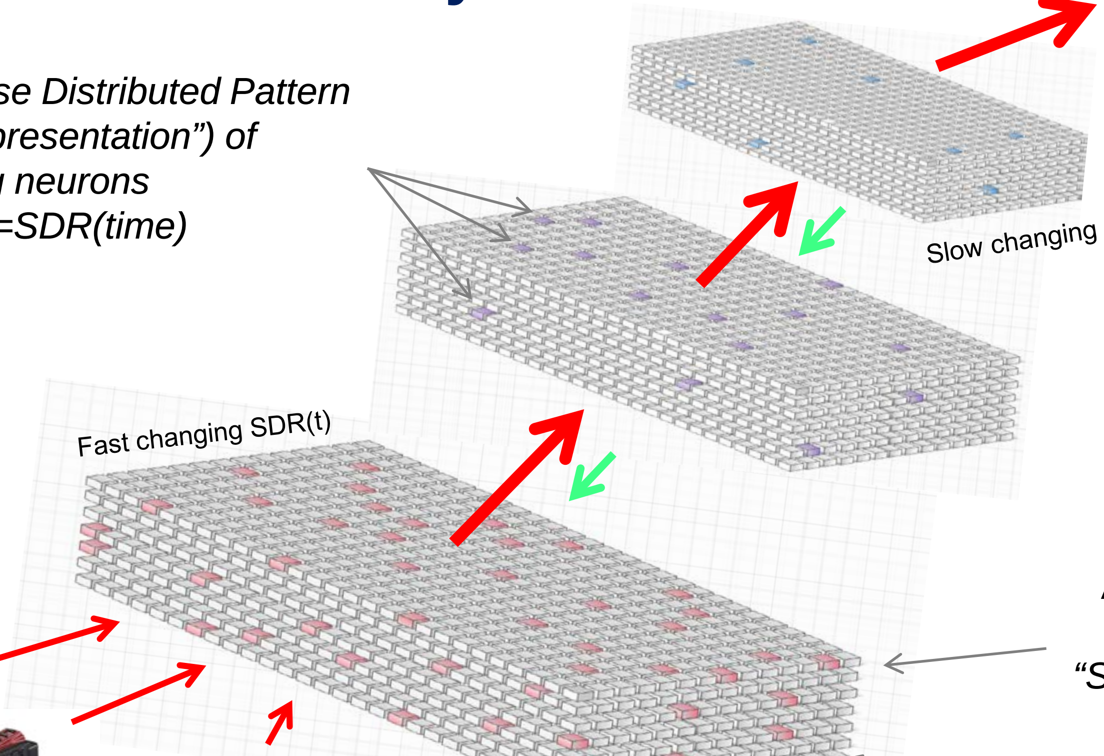
Layer 6



One Neuron

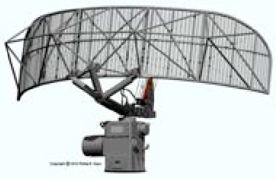
# Too Simple Neural Hierarchy

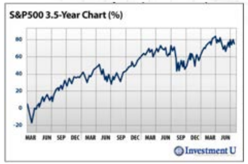
*Sparse Distributed Pattern (“Representation”) of firing neurons*
*SDR=SDR(time)*



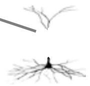

**OUTPUTS:**
Predictions
Contexts
Stable Concepts
Motor commands

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





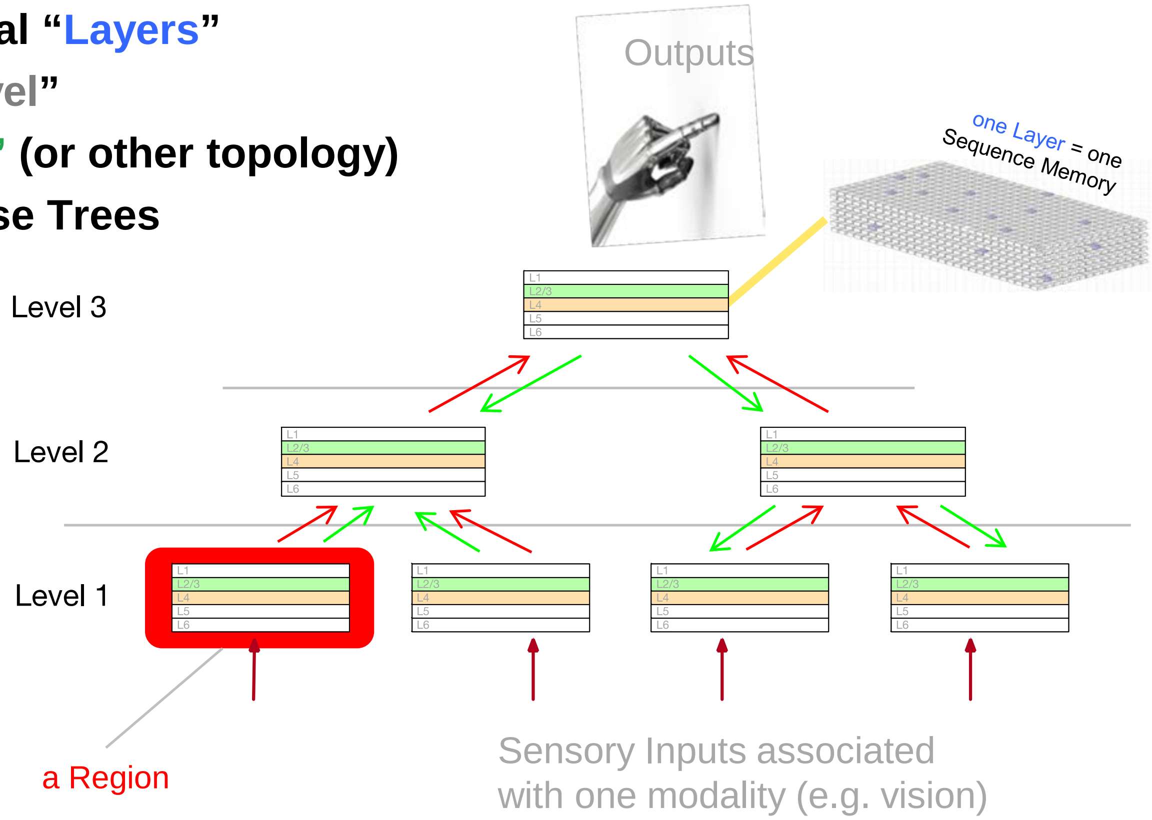

Array of columns *of neurons aka “Sequence Memory”* *(J.Hawkins et.al.)*



one neuron

# Layers, Levels and Regions

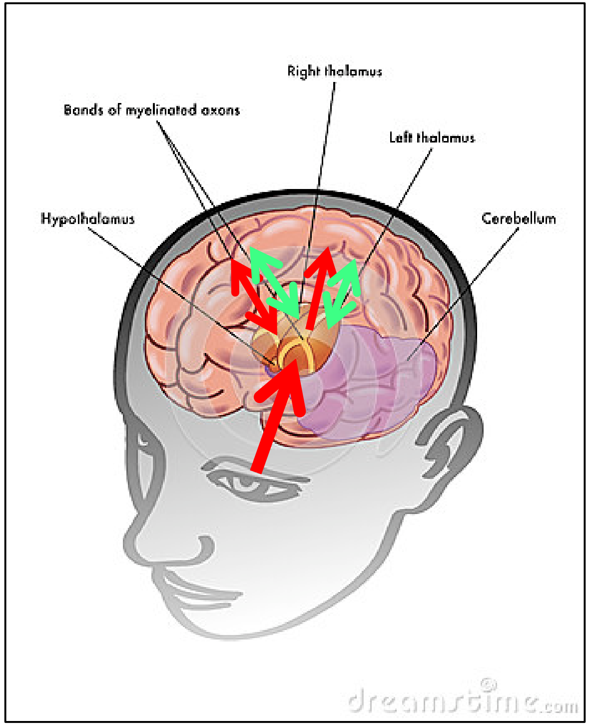
- Regions are stacks of 5 neural "Layers"
- Multiple Regions form a "Level"
- Multiple Levels form a "Tree" (or other topology)
- System is a collection of these Trees
  - – but see next slides



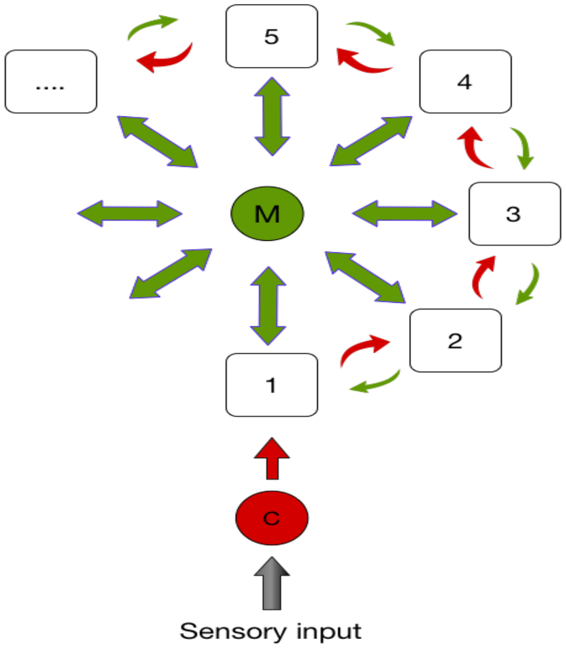
# Thalamus – two important Functions

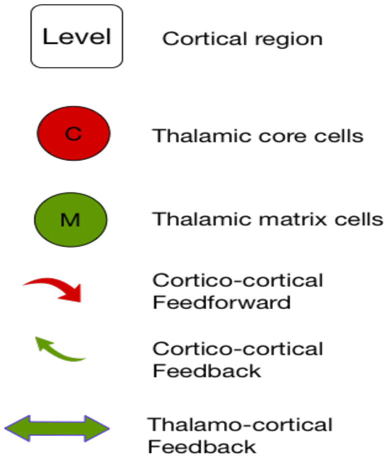
- **Central router for:**
  - – communication between
    - regions to regions and to sensors & motors
    - local neural hierarchies
  - – feedback between regions

- **Blackboard for sharing data between regions**



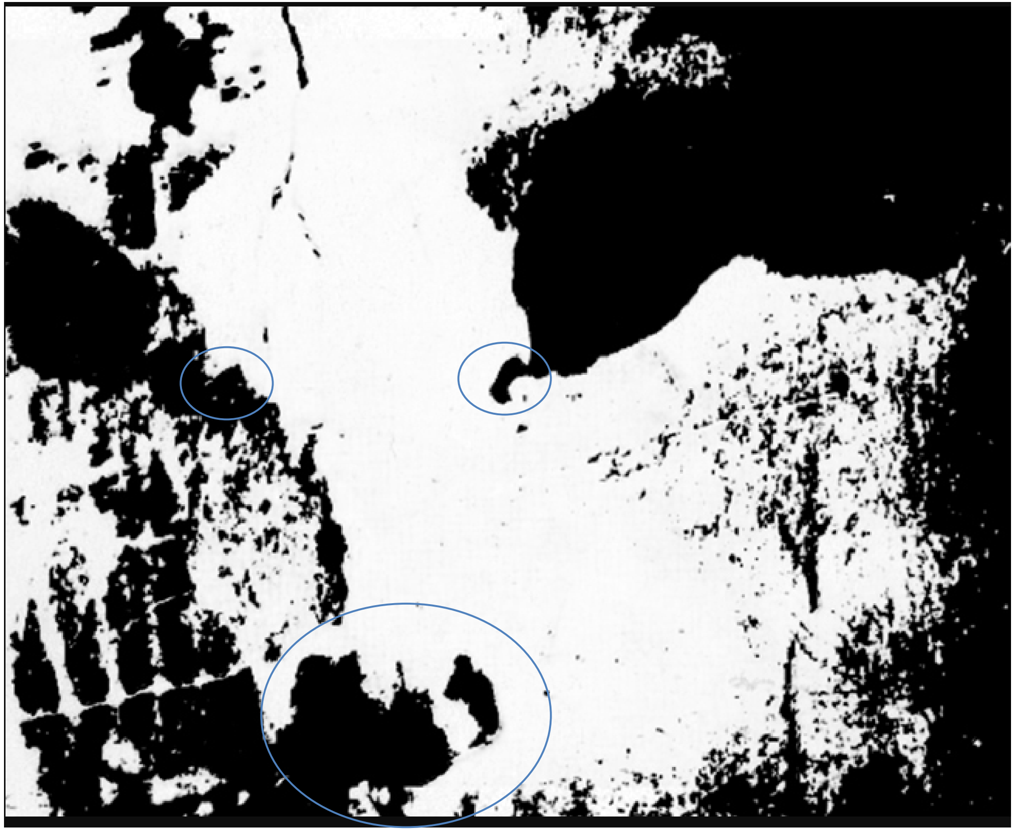
# Feedback through the Thalamus

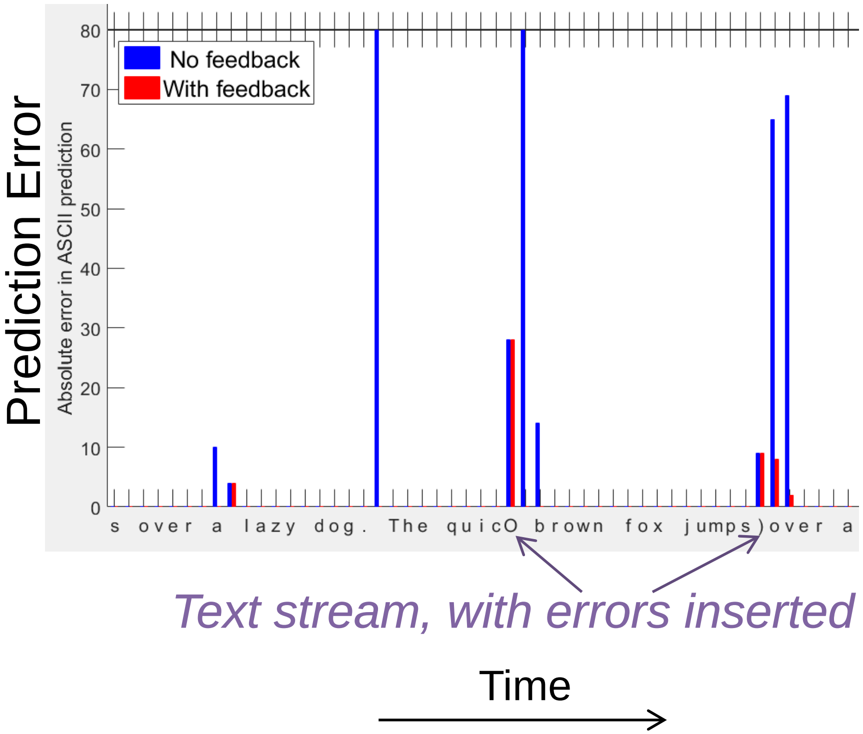



Thalamus metaphors:
"Internal sketchpad" Erich Harth (1982, 1993,1995)
"Active blackboard" David Mumford (1991,1992)
"Blackboard" Newman and Baars (1993)

# The Importance of Feedback

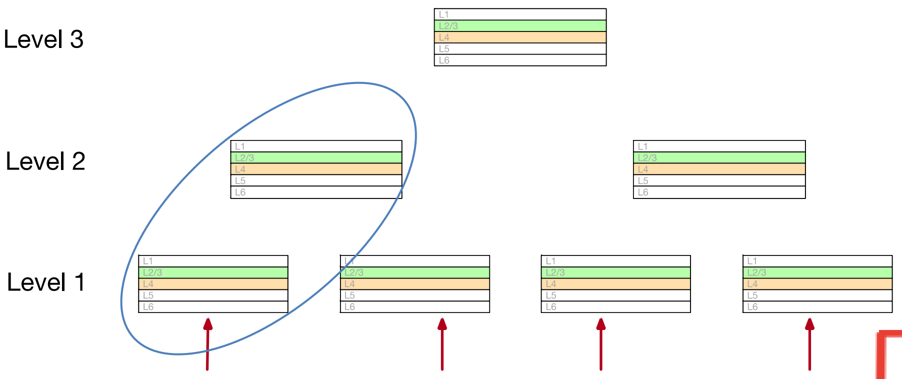


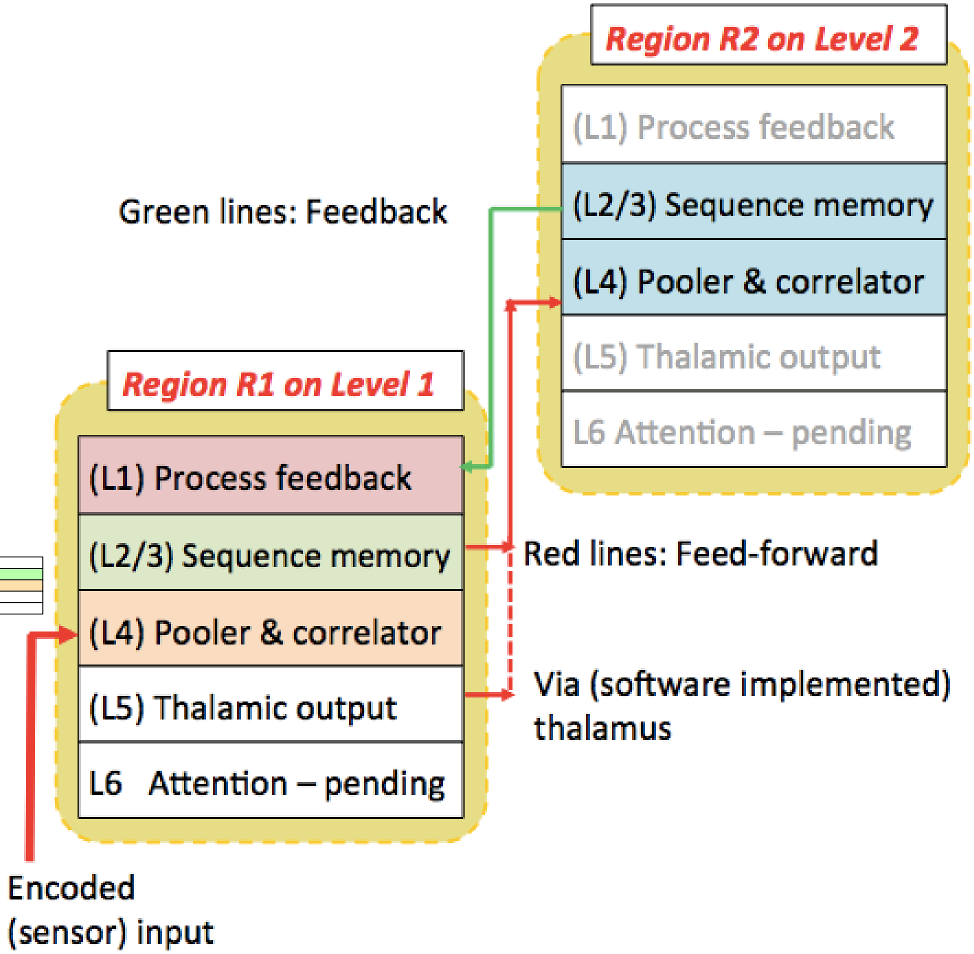


# Current Status…

# Baby CAL

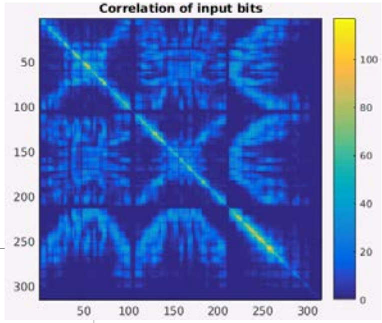
- 2 regions on 2 levels
- sufficient to test key functions of CAL



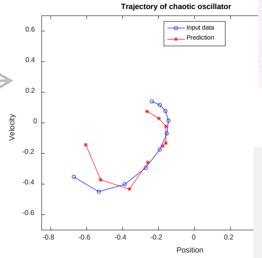



# (Baby) CAL in four Video Demos (outside)

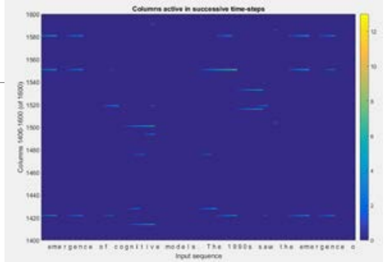
- **'Correlator' Video**
  – Dynamic formation of synapses connecting neurons which are firing simultaneously due to correlated inputs



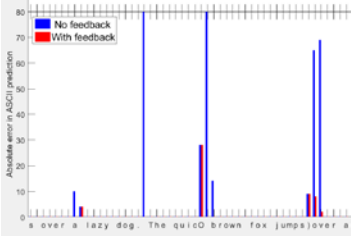

- **'Sequence Memory' Video**
  – Prediction of phase-space behavior of a chaotic oscillator




- **'Temporal Pooler' Video**
  – Streaming text and persistent SDR(time) in upper Level 2

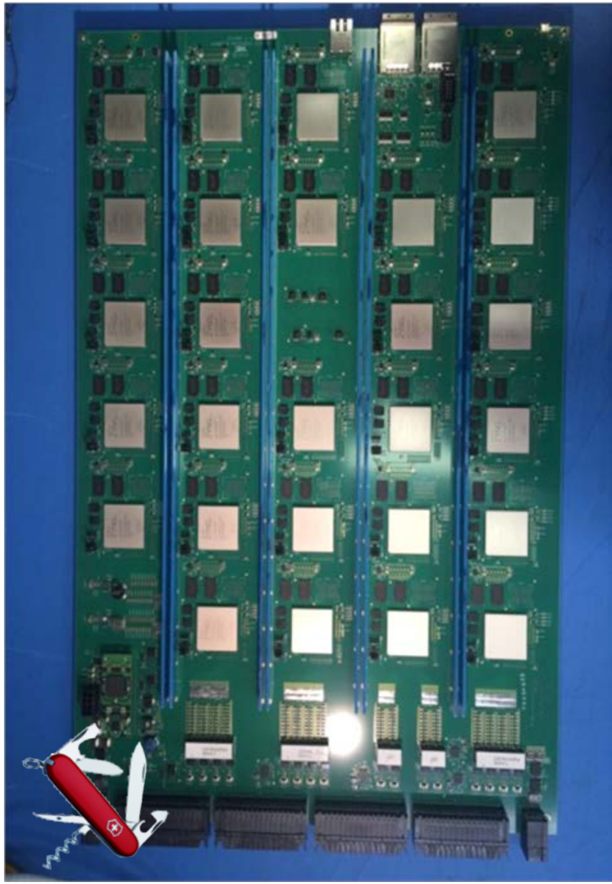



- **'Feedback' Video**
  – Streaming text, randomly damaged, is better predicted with feedback between Levels



# 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)**

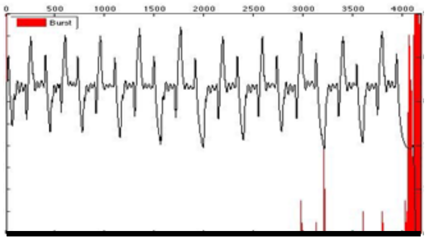


# Robots for Machine Intelligence

- **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 !

# Team

| | | |
|---|---|---|
| Hernan | Badenes | |
| Geoffrey | Burr | |
| Ken | Clarkson | |
| Chuck | Cox | |
| Jacquana | Diep | |
| Harald | Huels | |
| Wayne | Imaino | |
| Tomasz | Kornuta | |
| Arvind | Kumar | |
| Hyong-Euk | Lee | (Partner) |
| Pritish | Narayanan | |
| Ahmet | Ozcan | |
| David | Pease | |
| Kamil | Rocki | |
| Campbell | Scott | |
| Ryusei | Shingaki | (Partner) |
| Jayram | Thathachar | |
| Winfried | Wilcke | |

# Thank you!