IBM Systems
Cognitive Systems

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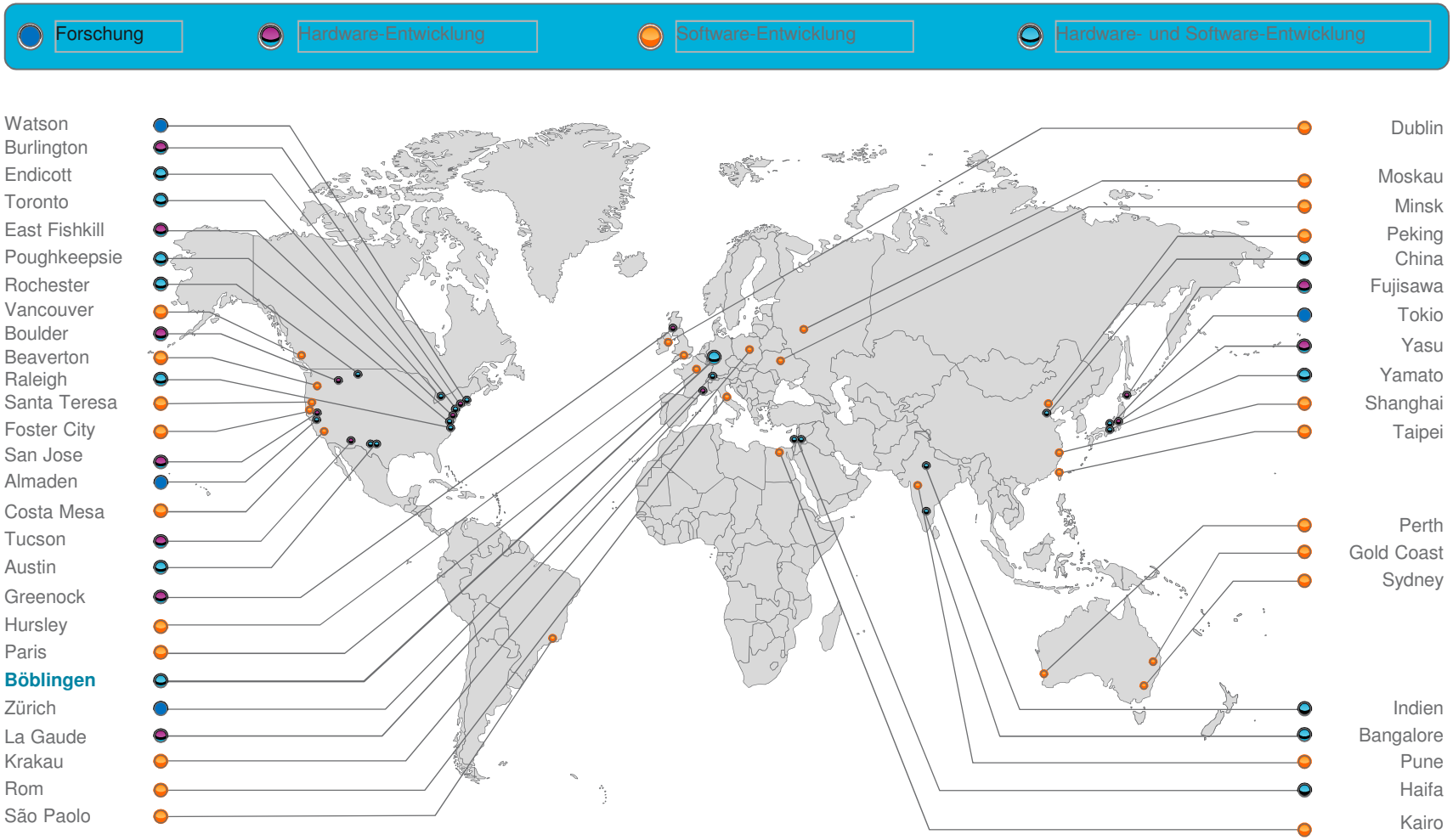
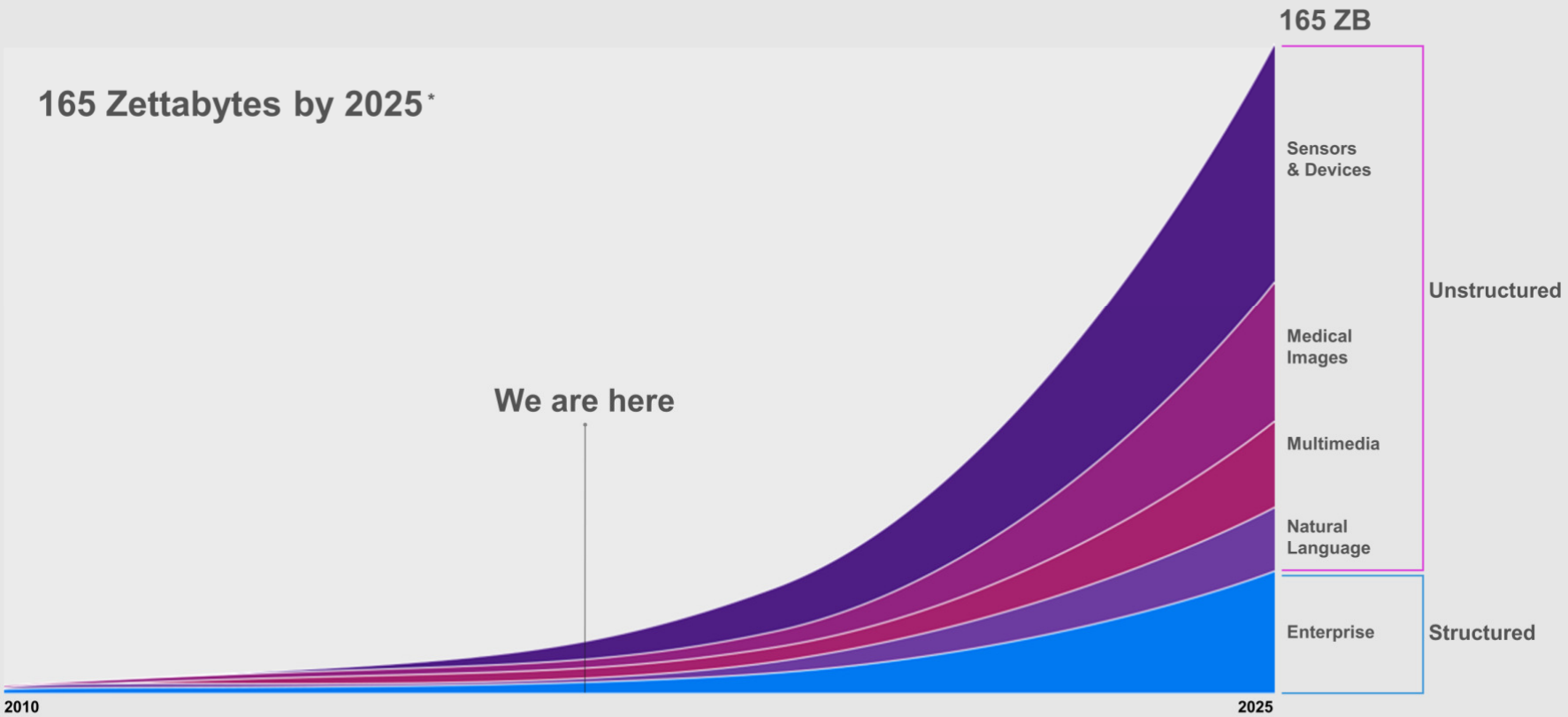
IBM Research & Development



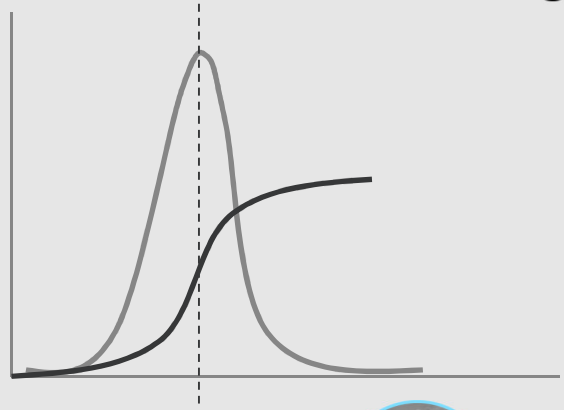
Digitale Transformation

Data is **transforming every industry**



*Source IDC. IBM projections based on analyst report

The next revolution is to **augment human cognition**



The Industrial Revolution

Steam and Railways

Steel, Electricity and Heavy Engineering

Oil, Automobiles and Mass Production

Information and Telecom

Cognitive Era

Augmenting Human Intelligence

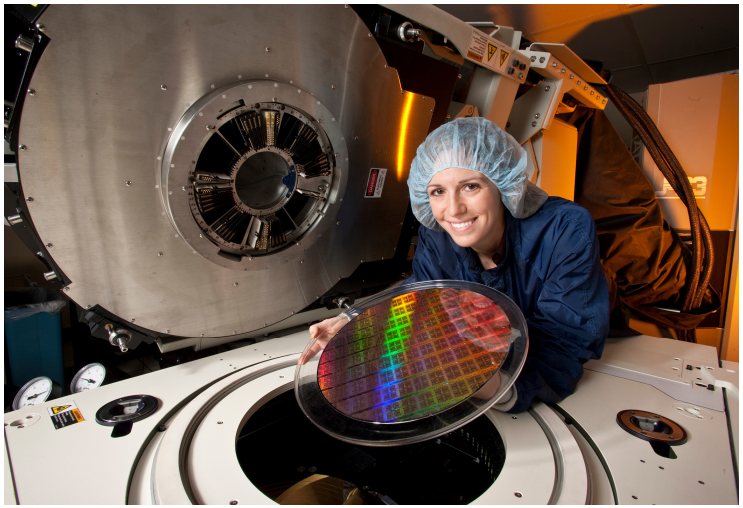
- Learn at scale
- Reason with purpose
- Interact naturally with us

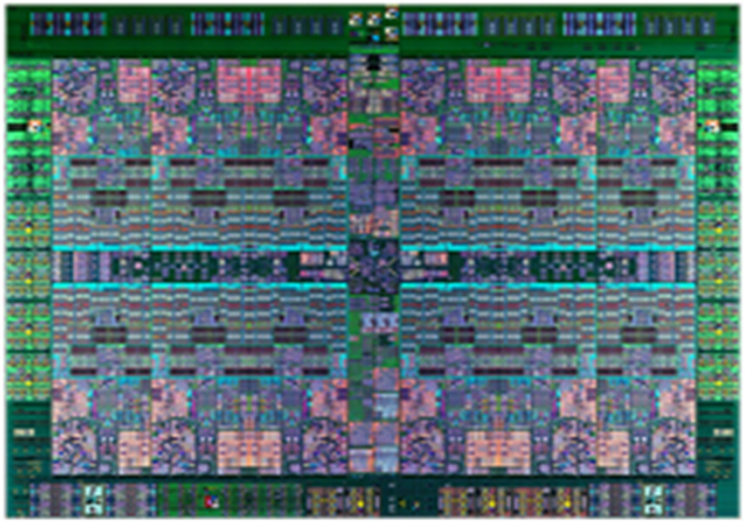
Powered by data

1700 — Today

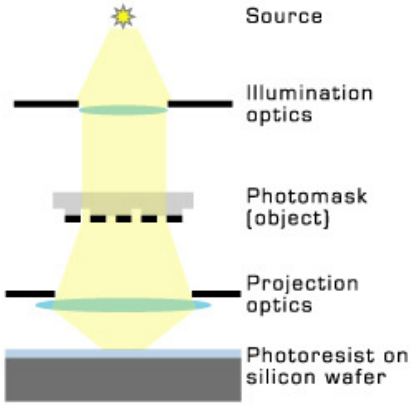
Source: Adapted from the work of Carlota Perez

Photo - Lithography

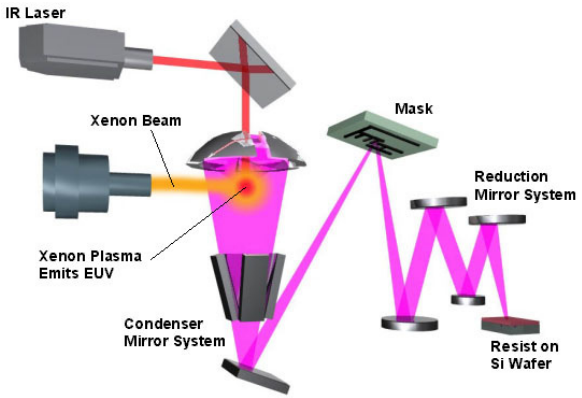




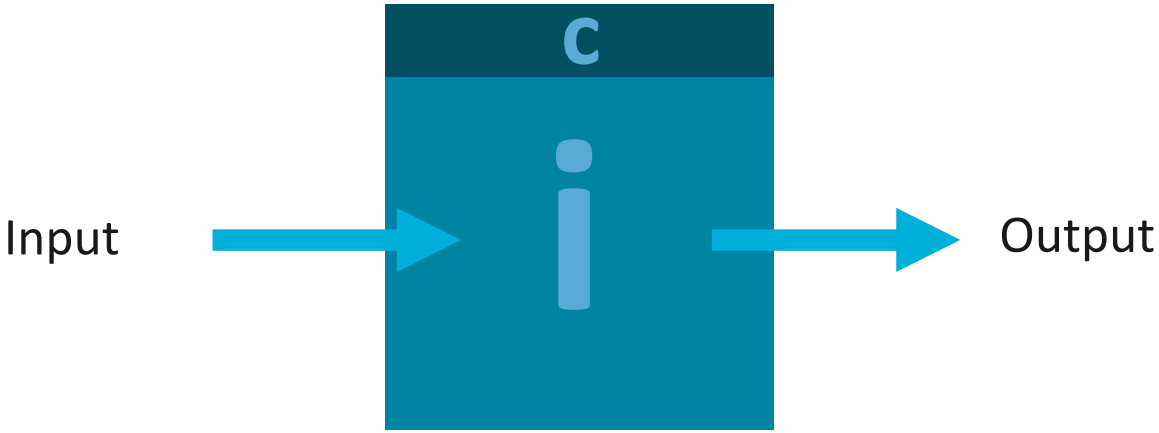
UV – Lithography 193 nm



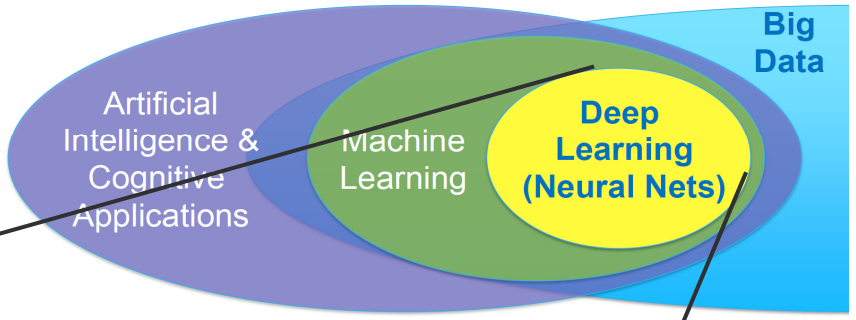
eUV – Lithography 13 nm

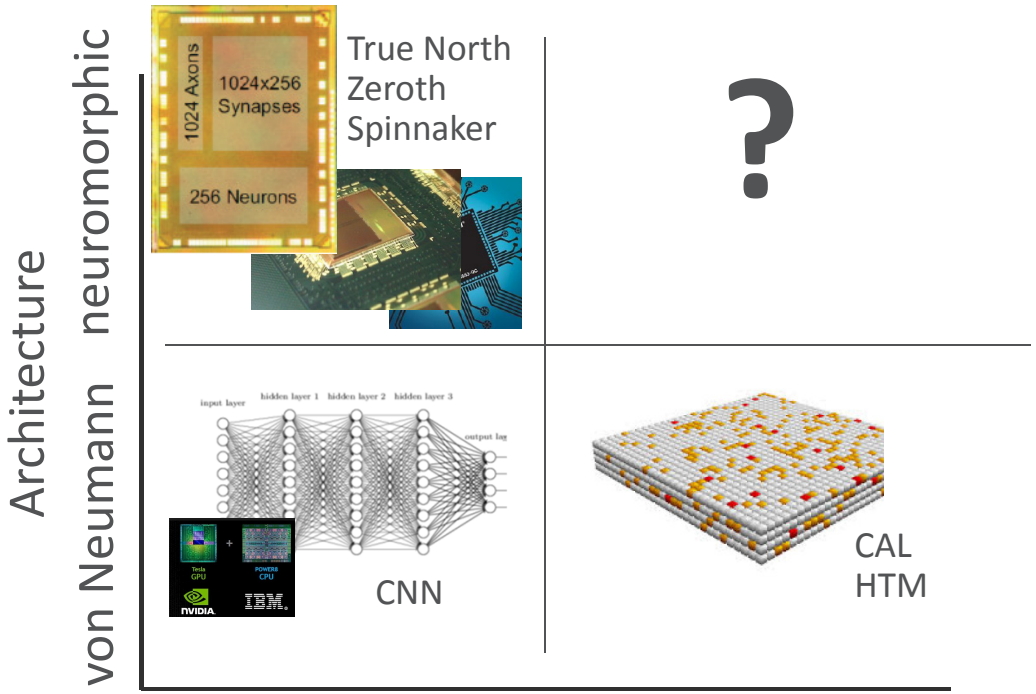


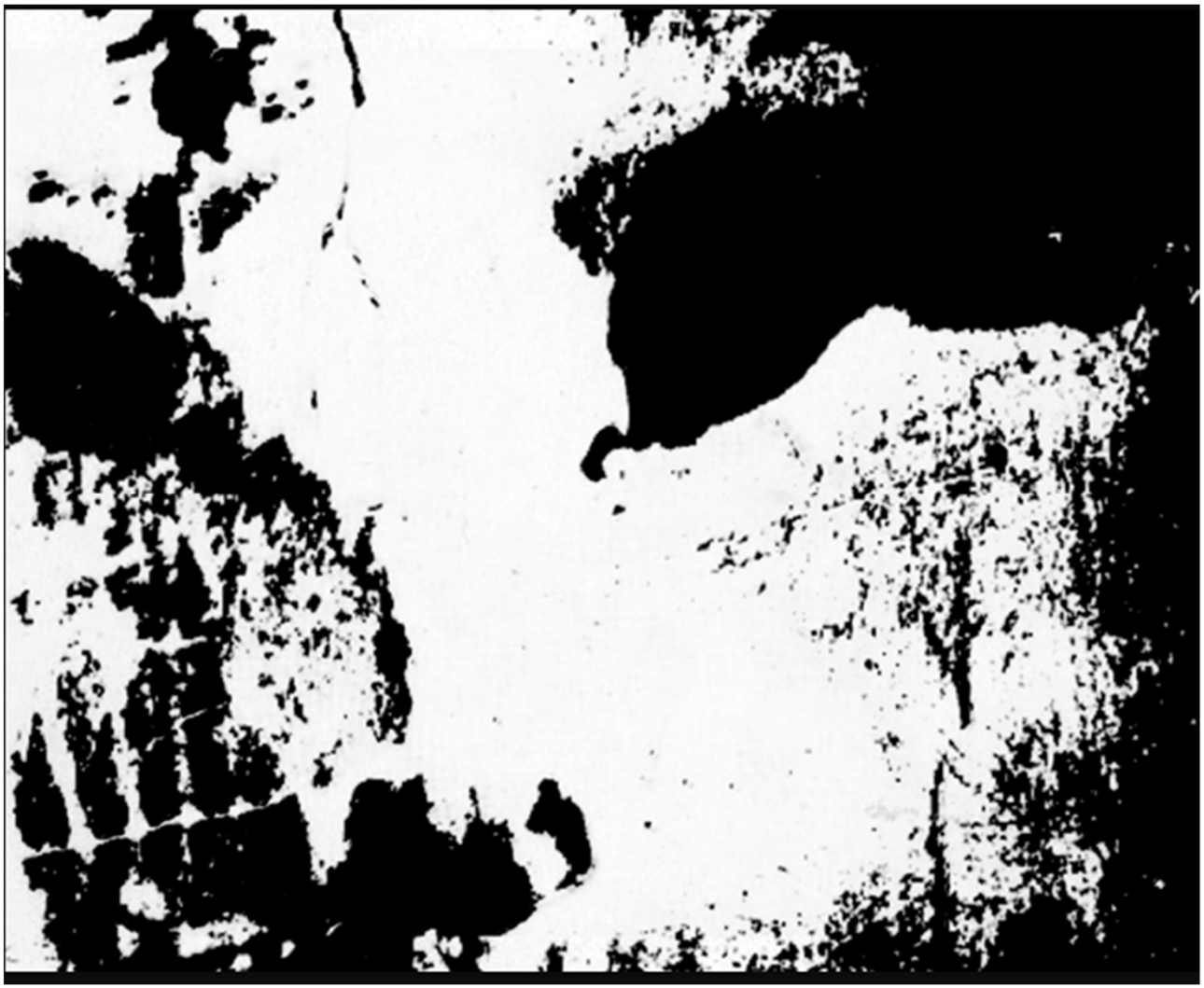
Artificial Intelligence



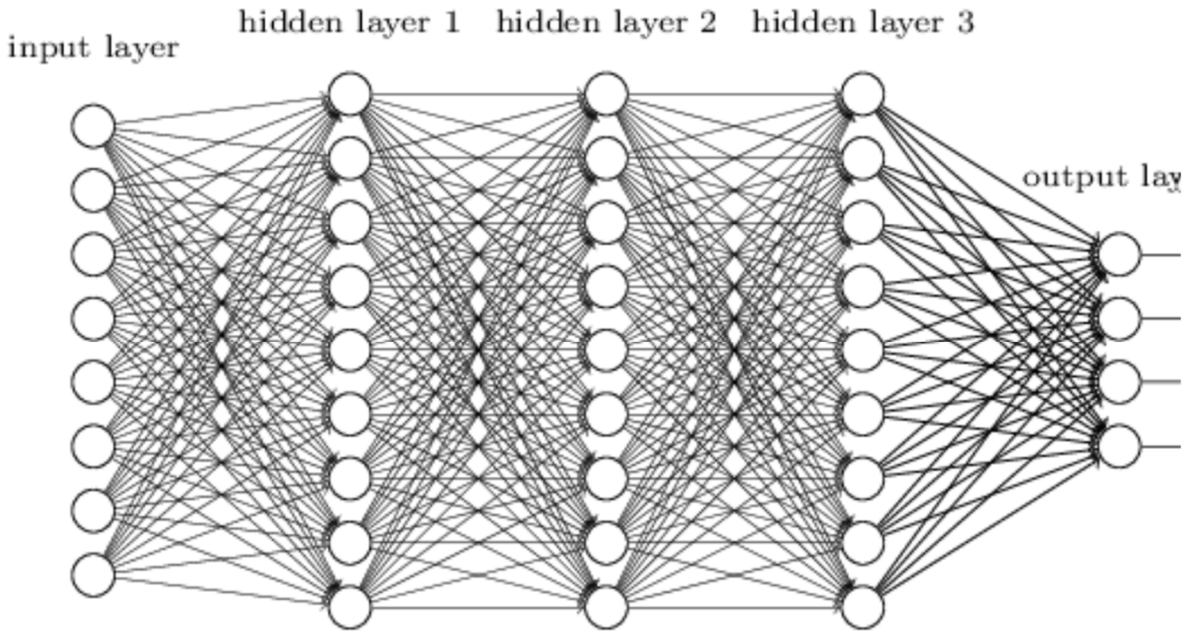
Artificial Intelligence







Neural Networks



Stochastic Gradient Descent

Function:

$$J(\theta_1, \theta_2) = {\theta_1}^2 + {\theta_2}^2$$

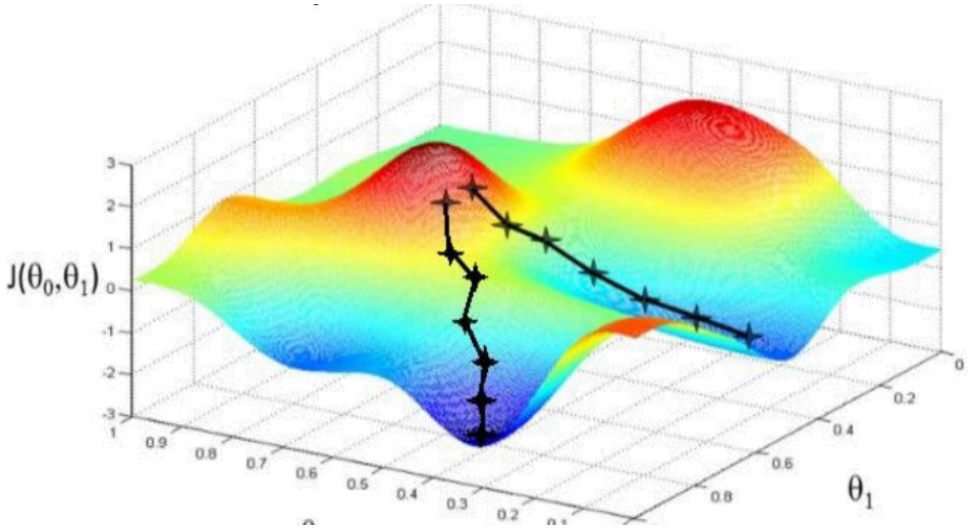
Objective:

$$\min_{\theta_1, \theta_2} J(\theta_1, \theta_2)$$

Update rules:

$$\theta_1 := \theta_1 - \alpha \frac{d}{d\theta_1} J(\theta_1, \theta_2)$$

$$\theta_2 := \theta_2 - \alpha \frac{d}{d\theta_2} J(\theta_1, \theta_2)$$

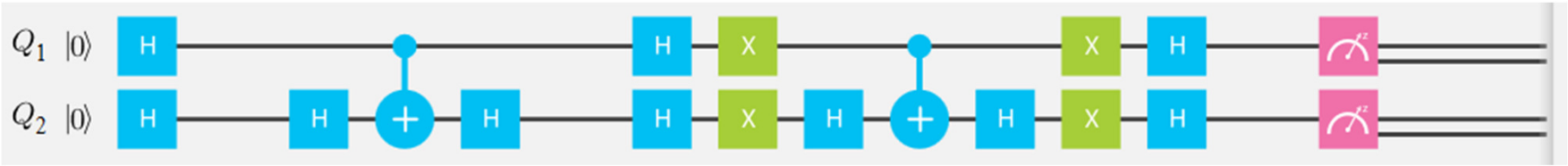


Derivatives:

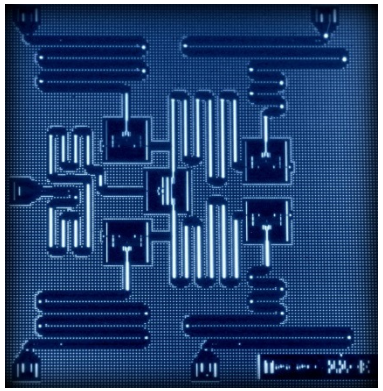
$$\frac{d}{d\theta_1} J(\theta_1, \theta_2) = \frac{d}{d\theta_1} {\theta_1}^2 + \frac{d}{d\theta_1} {\theta_2}^2 = 2\theta_1$$

$$\frac{d}{d\theta_2} J(\theta_1, \theta_2) = \frac{d}{d\theta_2} {\theta_1}^2 + \frac{d}{d\theta_2} {\theta_2}^2 = 2\theta_2$$

Quantum Computing

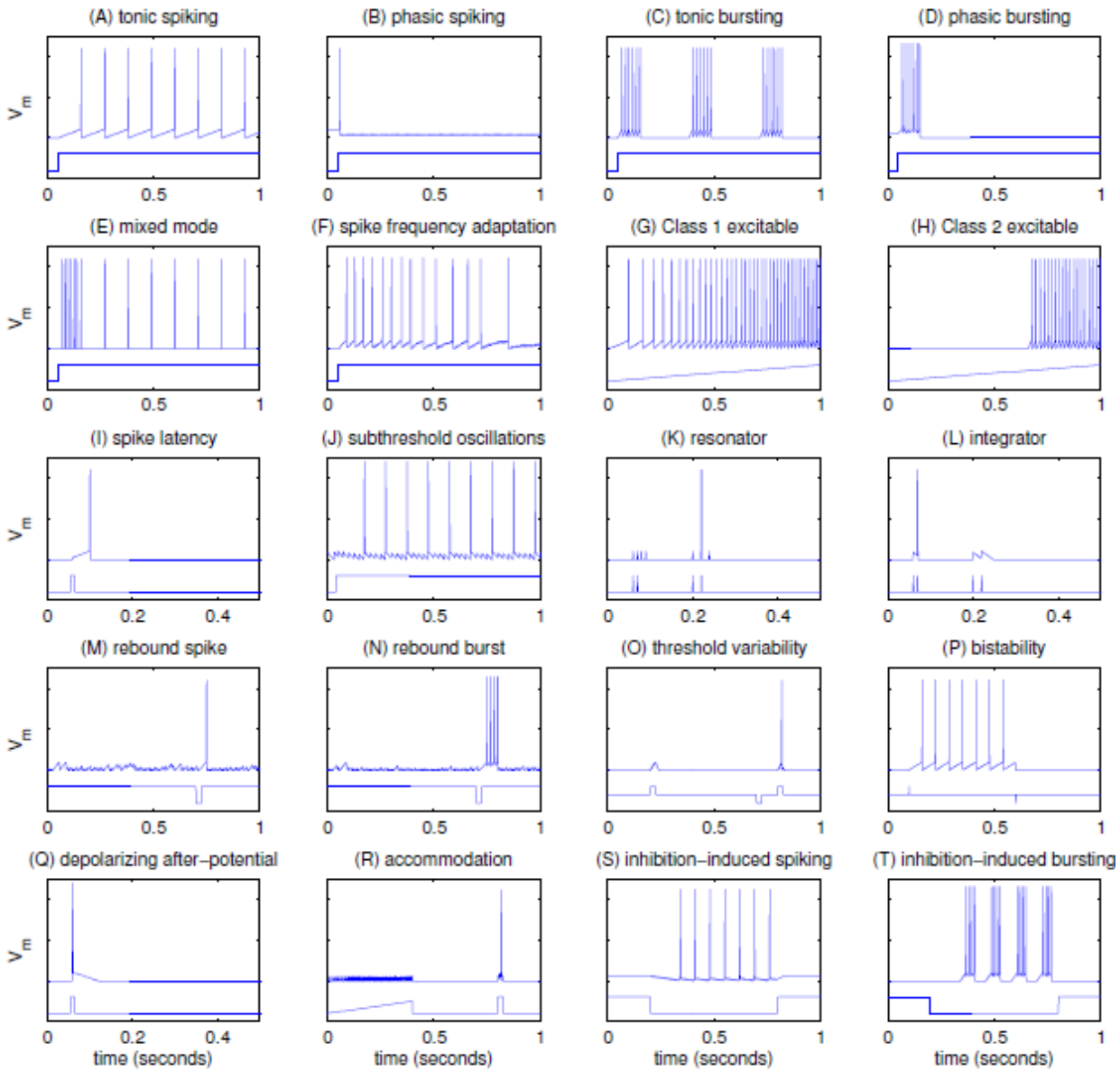


$|0\rangle = \begin{pmatrix} 1 \\ 0 \end{pmatrix}$ $|1\rangle = \begin{pmatrix} 0 \\ 1 \end{pmatrix}$



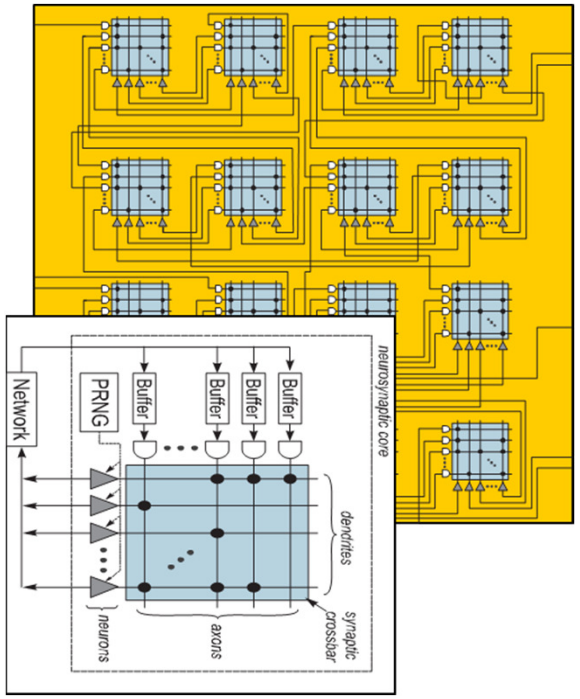
Spiking Neurons

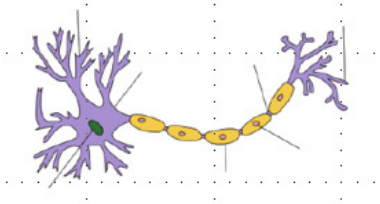
Prominent Features of Spiking Neurons after Izhikevich



Neuron Function

- Emulation of analog behaviour by +/- 255 INT variable
- 2-dimensional on-chip synaptic weighted network and off-chip packet based thru-neuron routing for multi-chip scaling
- Update of Synaptic network every ms (logical / biological clock), internal processing ~ 1MHz
- Neuron fires a spike (45 pJ) to the network if in the last update cycle a threshold was reached or exceeded
- Stochastic and leak behaviour configurable





Membrane potential for neuron j at time t

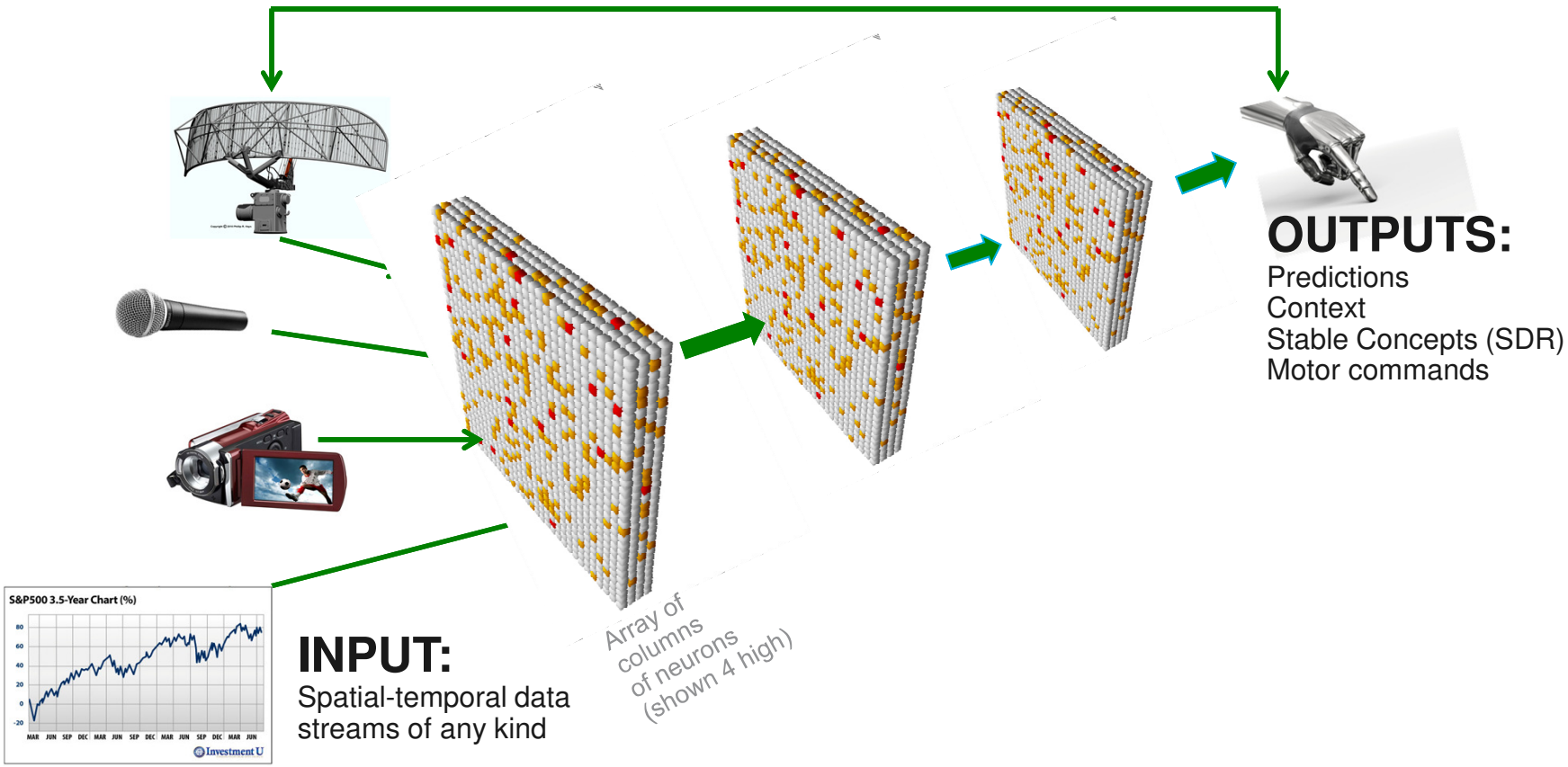
$$V_j(t) = V_j(t-1) + \sum_{i=0}^{255} A_i(t) * z_{ij} * [(1 - b_j) * s_j + sign(s_j) * b_j * F(|s_j|, q_j)] + Leak$$

Leak

$$V_j(t) = V_j(t-1) + \begin{pmatrix} +1 \\ 0 \\ -1 \end{pmatrix} * [(1 - c_j) * k_j + sign(k_j) * c_j * F(|k_j|, q_j)]$$

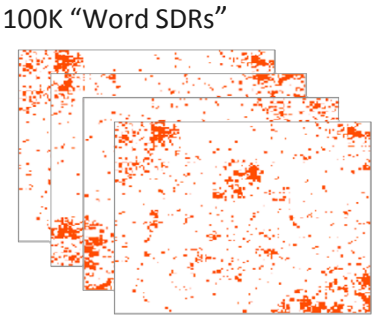
“ Universal Cortical Engine “

Sparse Distributed Representations (SDR)

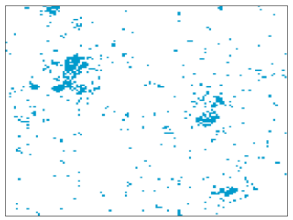


Find semantic similarities of words in Wikipedia

Document corpus
(e.g. Wikipedia)

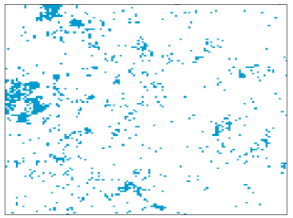


Apple



minus

Fruit



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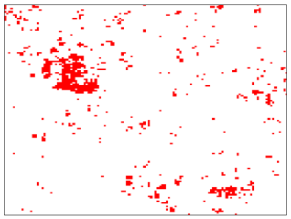
Computer



runners up were
Macintosh
Microsoft
Mac
Linux
Operating system
….

IBM Watson

System Specifications

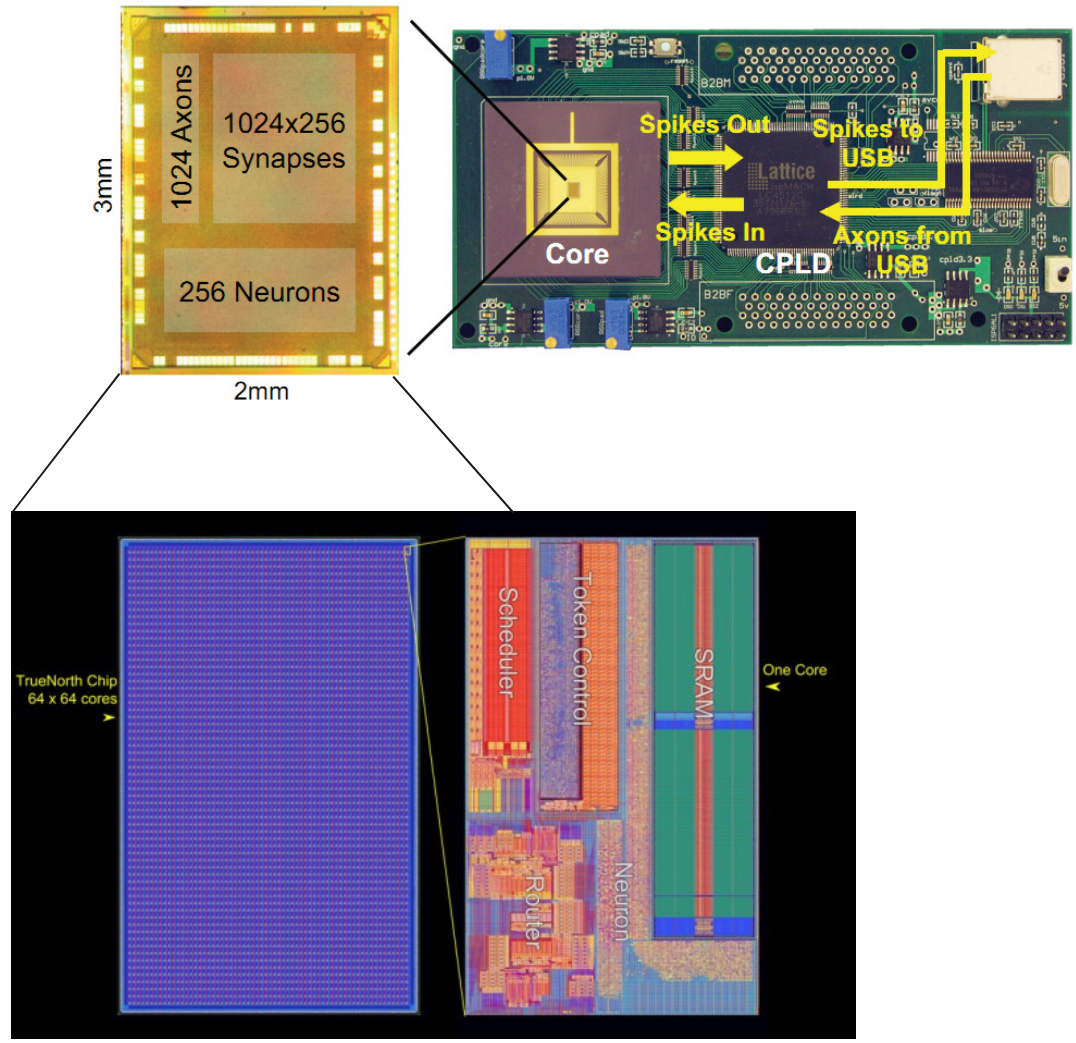
- 2880 Processing Cores
- 90 IBM P750 Servers
- 16 Terabytes Memory (RAM) – 20TB Disk
- 80 Teraflops (80 trillion operations per second)
- Workload Optimized Systems

IBM Technology Depth

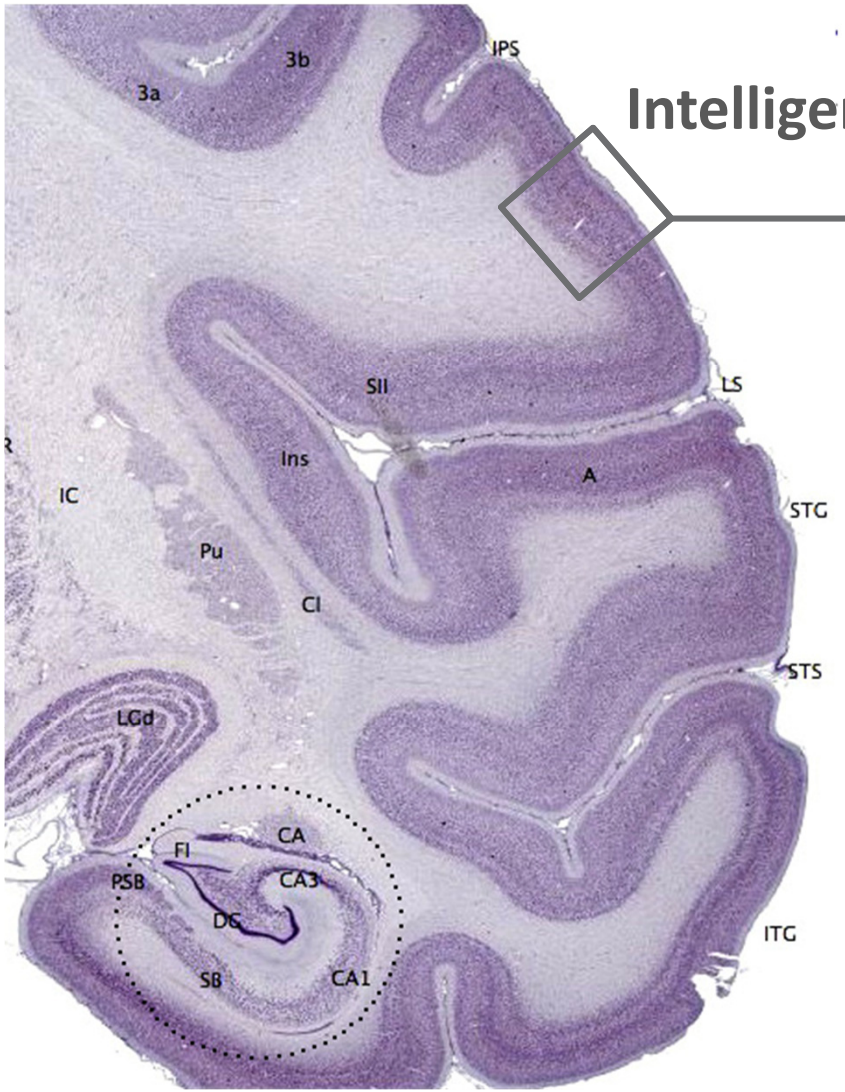
- Content Analytics
- Business Analytics
- Big Data
- Databases / Data Warehouses

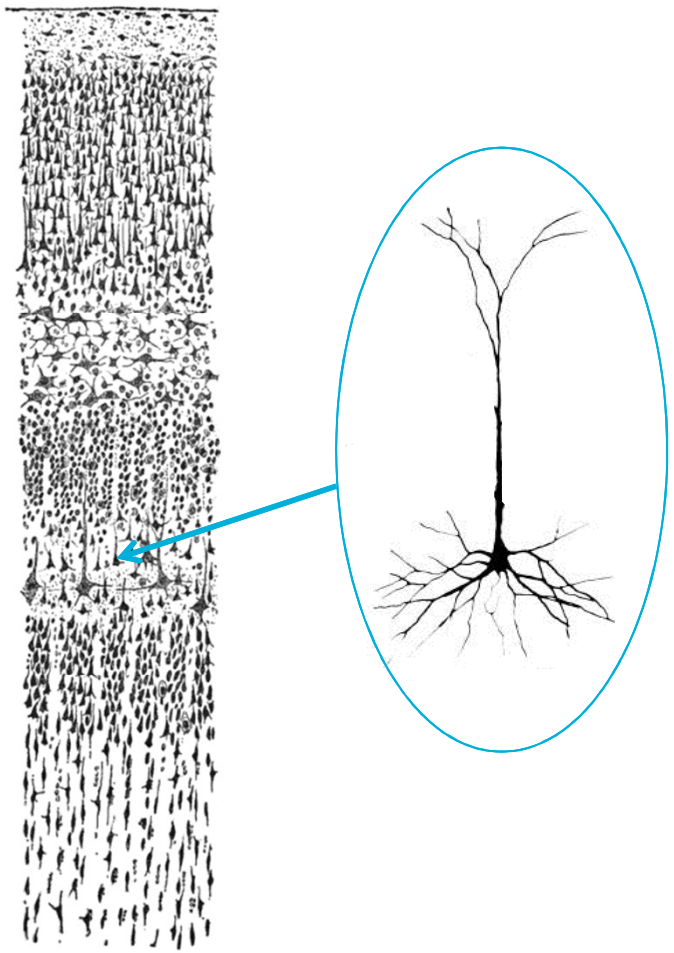
Synapse Hardware

TrueNorth	
Technology	28nm
Year	2012
Transistor Count	**5.4 billion**
Power	0.05W

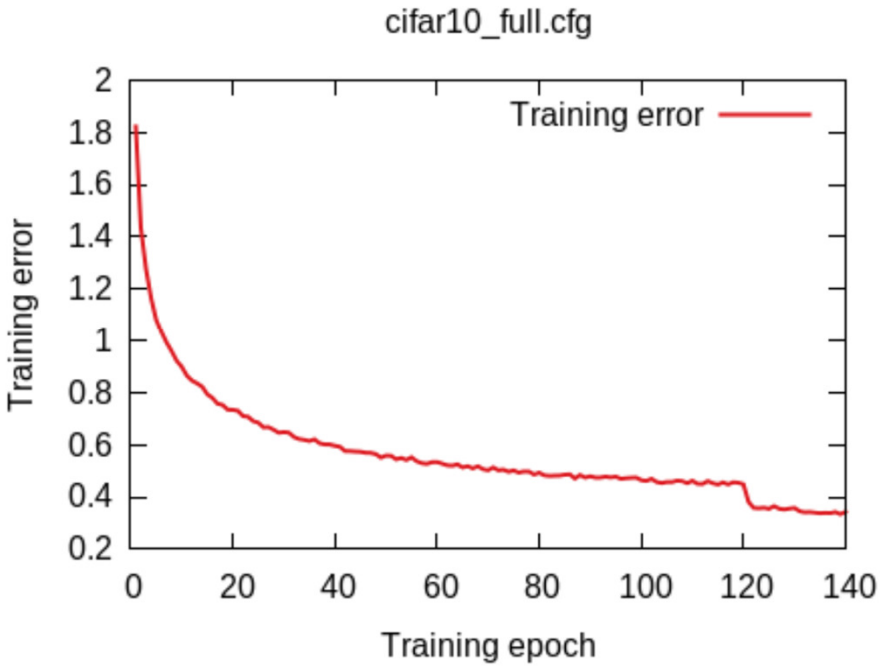


Intelligence

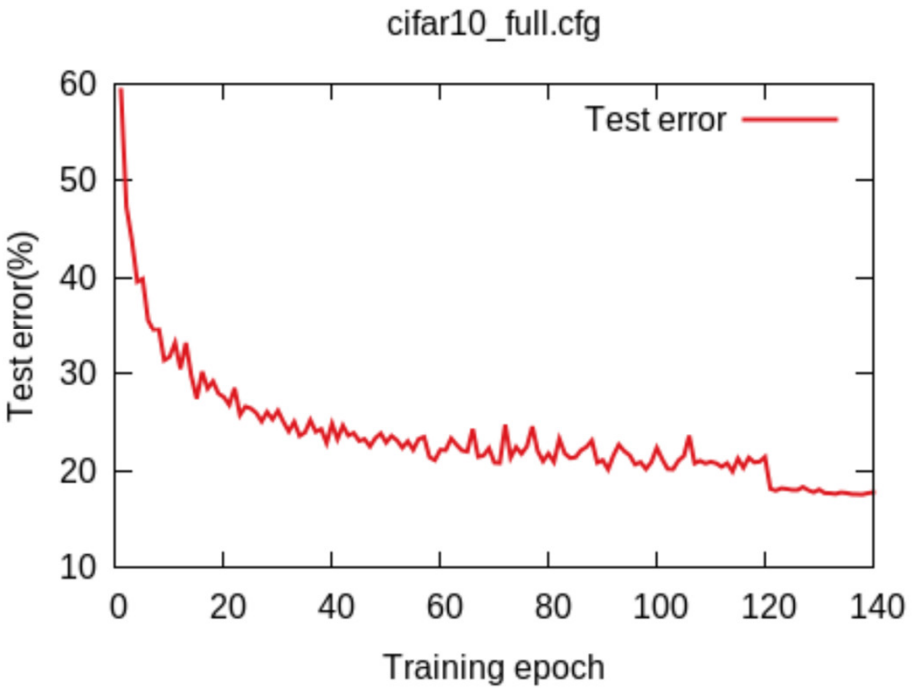


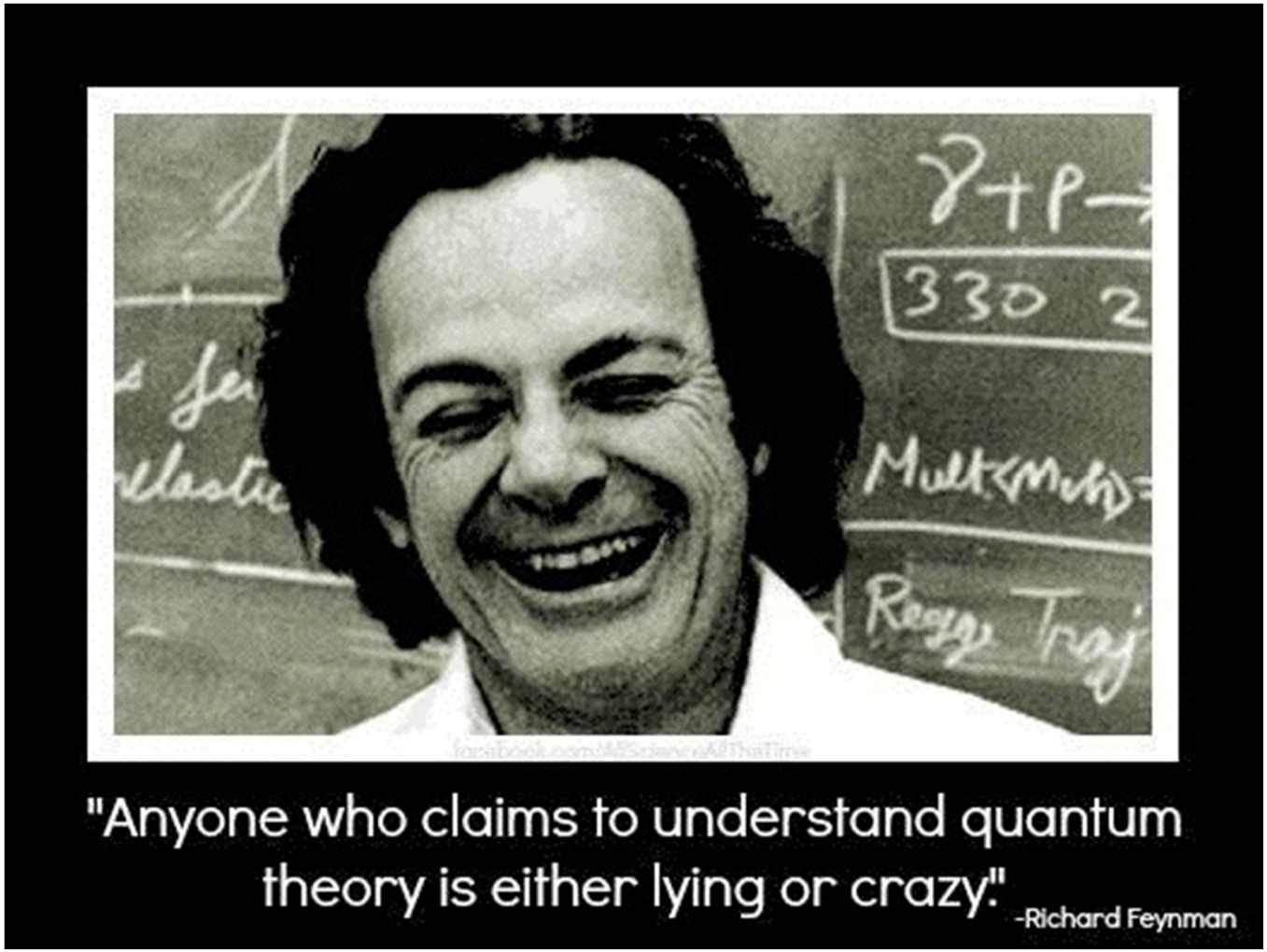


Errorfunctions



Cross-Entropy Error (C) during training



Test-Error during training

Quantum Computing