



Deep Learning

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A stylized illustration of a neuron. The cell body is a translucent blue sphere with a purple nucleus. Numerous thin, blue, branching processes extend from the cell body, resembling dendrites and axons. Several of these processes are highlighted with bright orange, glowing points, suggesting active synapses or signal transmission. The background is dark blue with some faint, out-of-focus light spots.

What is Deep Learning?

What is Deep Learning?

- Uses raw data to automatically discover the representations needed for detection or classification
- Has multiple levels of representation, obtained by composing simple but non-linear modules that each transform the representation at one level into one at a higher, slightly more abstract level



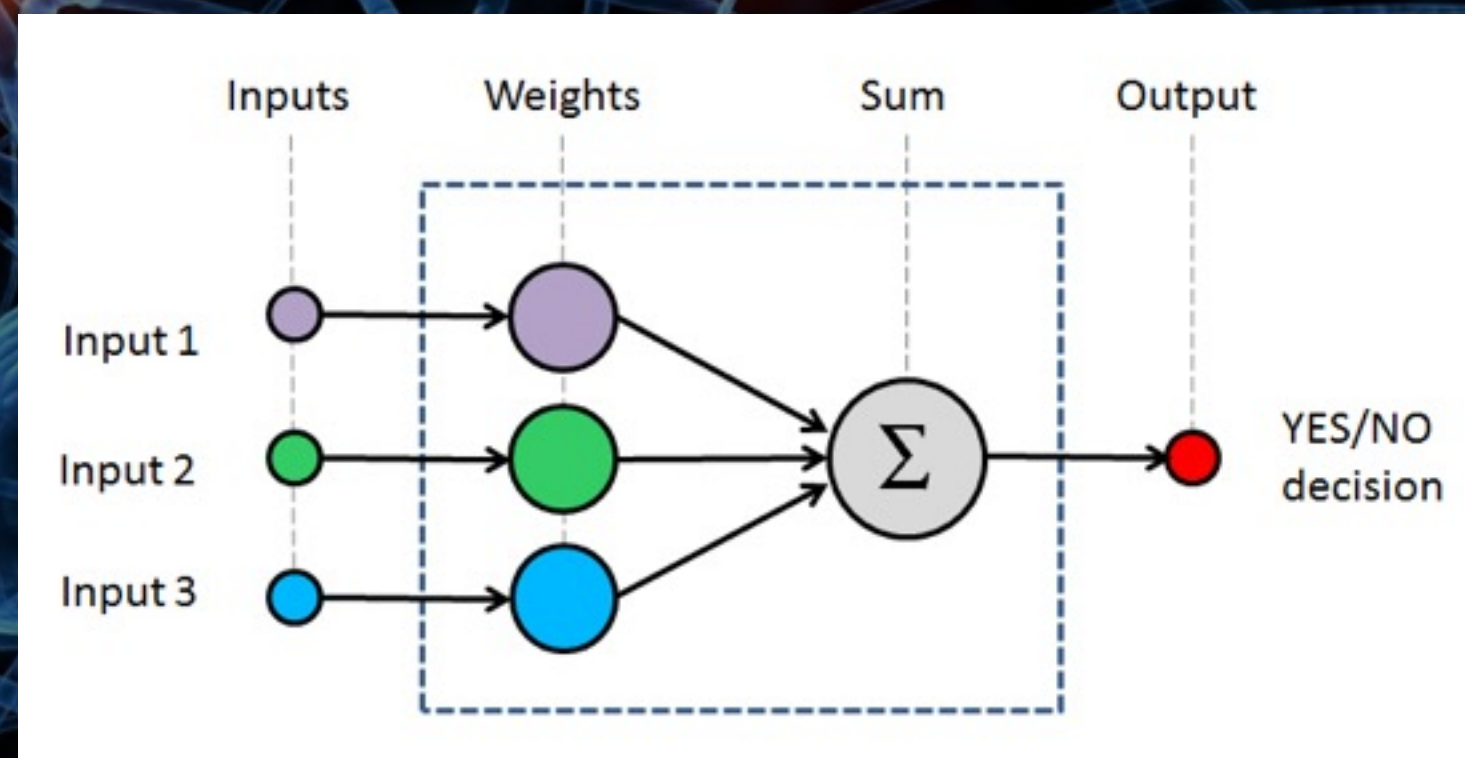
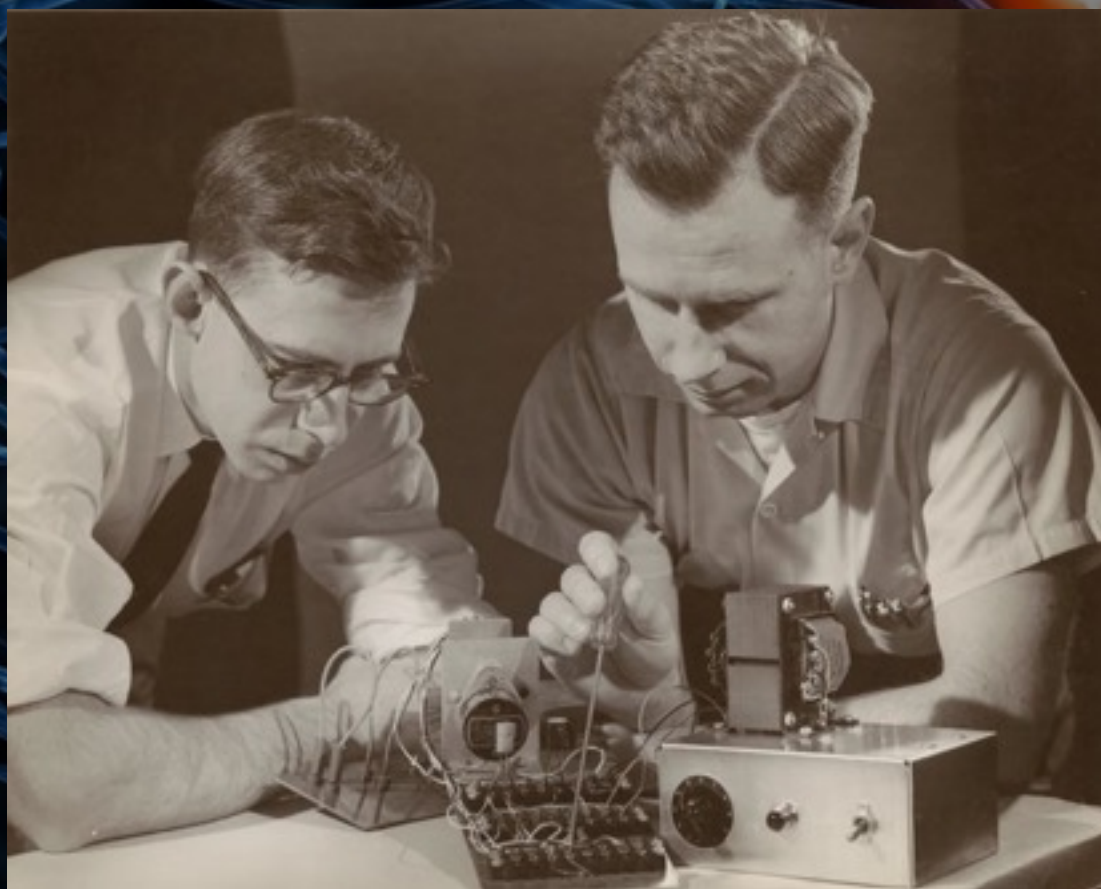
Neural Nets

Frank Rosenblatt (1928–1971)



- Invented the Perceptron in 1957
- The IEEE's annual award for outstanding contributions to the advancement of the design, practice, techniques, or theory in biologically and linguistically motivated computational paradigms is named in his honor

The Perceptron



The Perceptron

1. Calculate the output:

$$\begin{aligned} y_j(t) &= f[\mathbf{w}(t) \cdot \mathbf{x}_j] \\ &= f[w_0(t) + w_1(t)x_{j,1} + w_2(t)x_{j,2} + \cdots + w_n(t)x_{j,n}] \end{aligned}$$

2. Update the weights:

$$w_i(t+1) = w_i(t) + \alpha(d_j - y_j(t))x_{j,i} \text{ for all } 0 \leq i \leq n$$

The Perceptron

“The Navy revealed the embryo of an electronic computer today that it expects will be able to walk, talk, see, write, reproduce itself and be conscious of its existence. ... Later Perceptrons will be able to recognize people and call out their names and instantly translate speech in one language to speech and writing in another language” – The New York Times (July 8 1958)

John McCarthy (1927–2011)



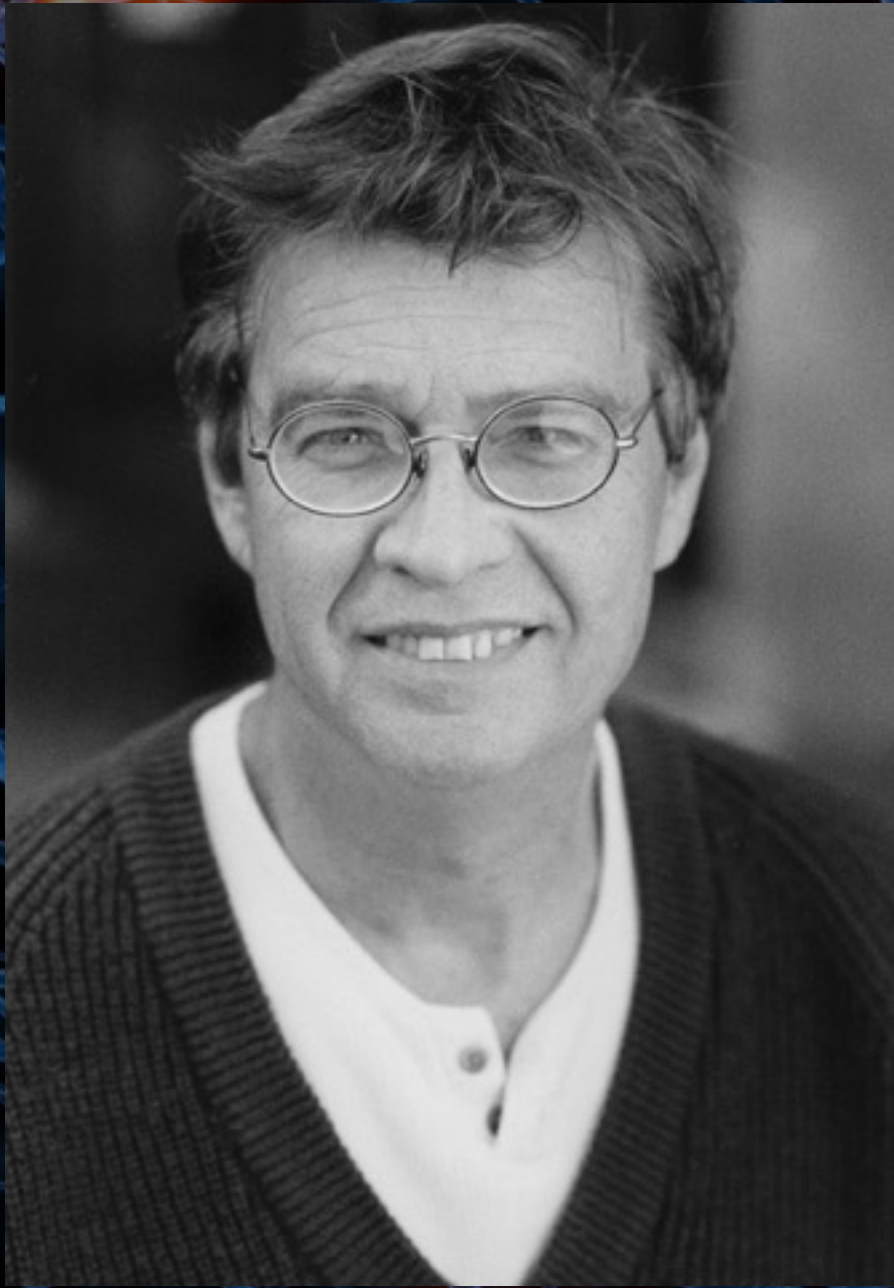
- ACM A.M. Turing Award in 1971
- Invented Lisp in 1958
- Invented Garbage Collectors
- Organized the first international conference in AI (Dartmouth 1956)

“Our ultimate objective is to make programs that learn from their experience as effectively as humans do.” – *John McCarthy*

The Perceptron (not good enough)

- Single layer Perceptron cannot implement XOR or XNOR
- Perceptrons with hidden layers need at least one neuron (with non-null weight) connected to every input

David Rumelhart (1942–2011)



- Member of the National Academy of Sciences
- Warren Medal (1993)
- Pioneer in cognitive neuroscience who explored the concept of connectionism
- Applied backpropagation to neural nets

*“All the knowledge is in the connections.” –
David E. Rumelhart*

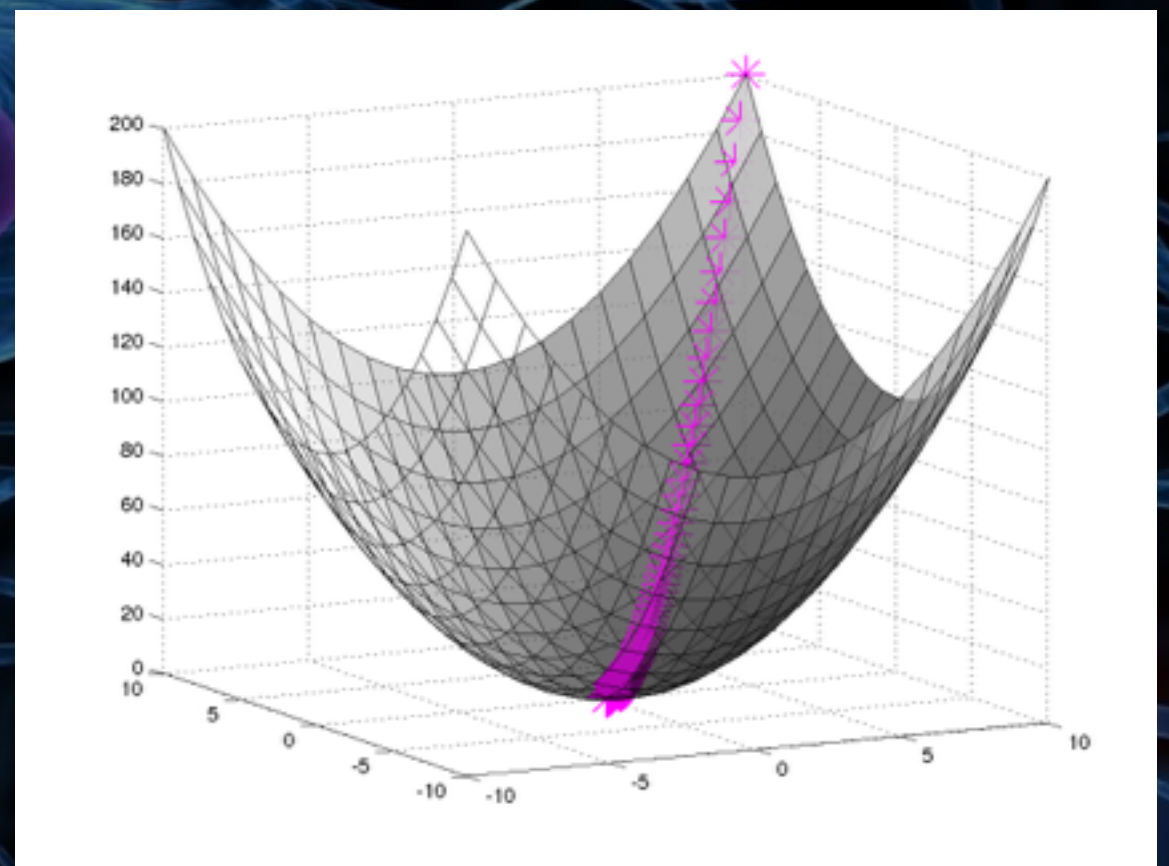
Backpropagation

The backpropagation algorithm looks for the minimum of the squared error function in weight space using the method of gradient descent.

$$E(\mathbf{w}) = \frac{1}{2} \sum_j (y_j - f_N(\mathbf{x}_j))^2$$

$$f_N(\mathbf{x}_j) = \sigma(\mathbf{x}_j)$$

$$\sigma(x) = \frac{1}{1 + e^{-x}}$$



$$\nabla E = \left(\frac{\partial E}{\partial w_1}, \dots, \frac{\partial E}{\partial w_n} \right)$$

Backpropagation

$$\frac{\partial E}{\partial w_{k,j}} = - \sum_i (y_i - o_i) \frac{\partial o_i}{\partial w_{k,j}} \quad o_i = f_{N_{1,j}}(\dots) = \sigma(f(\dots))$$

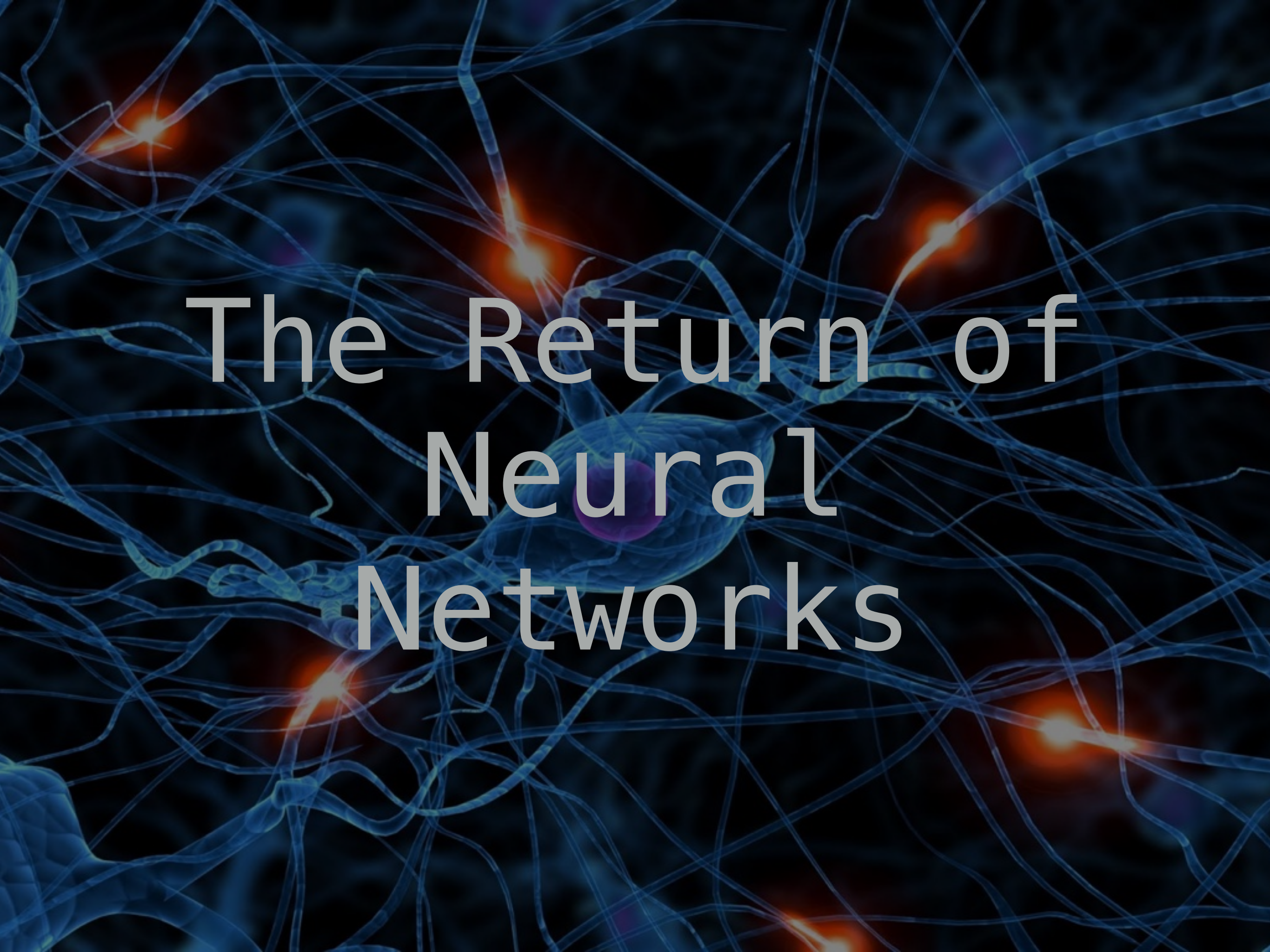
$$\frac{\partial E}{\partial w_{k,j}} = - \sum_i (y_i - o_i) \sigma'(f(\dots)) w_{j,i}$$

$$\sigma'(x) = \sigma(x)(1 - \sigma(x))$$

$$\mathbf{w} = \mathbf{w} + \eta o_j (1 - o_j) \left(\sum_i w_{j,i} (y_i - o_i) \right) \mathbf{z}$$

Backpropagation

- Begin with random weights.
- Evaluate an input, feeding it forward through the network.
- For each node compute the error, propagate it back to each of the nodes feeding it and update the weights for the node.
- Repeat the evaluation and update for new input, until all data is evaluated.

The background is a dark blue field filled with a complex, tangled web of thin, glowing blue lines that resemble neural connections or data pathways. Several bright, glowing orange-yellow nodes are scattered throughout the network, with one prominent node located near the center where the text is overlaid. The overall effect is a high-tech, futuristic representation of a neural network.

The Return of Neural Networks

The Deep Learning Conspiracy



Geoffrey
Hinton
(1947)



Yoshua
Bengio
(1964)



Yann
LeCun
(1960)

2006

- Hinton, G. E., Osindero, S. & Teh, Y.-W. *A fast learning algorithm for deep belief nets.*
- Bengio, Y., Lamblin, P., Popovici, D. & Larochelle, H. *Greedy layer-wise training of deep networks.*
- Ranzato, M., Poultney, C., Chopra, S. & LeCun, Y. *Efficient learning of sparse representations with an energy-based model.*



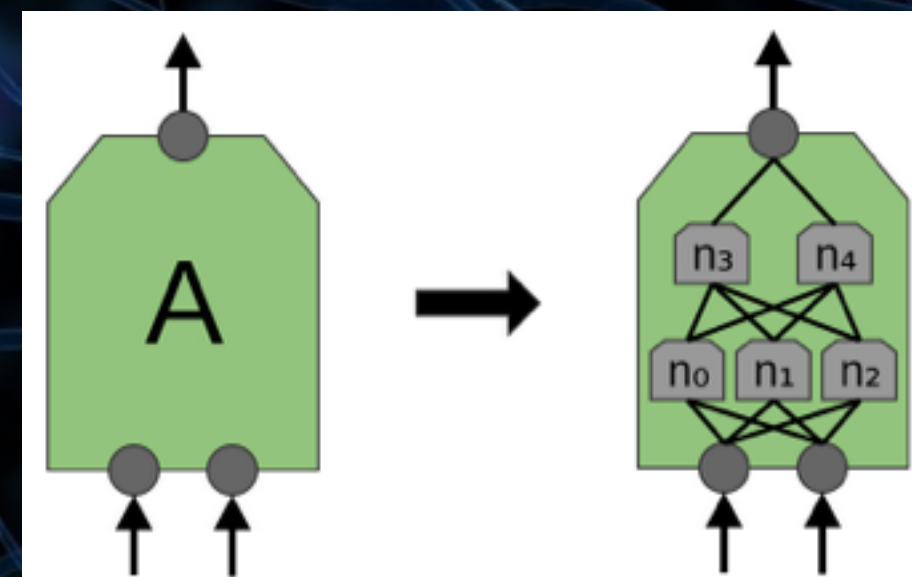
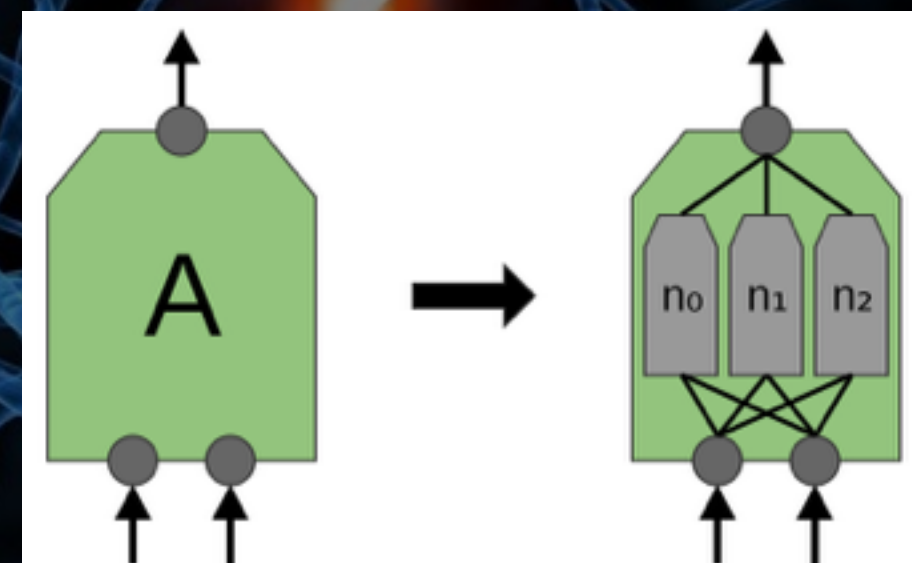
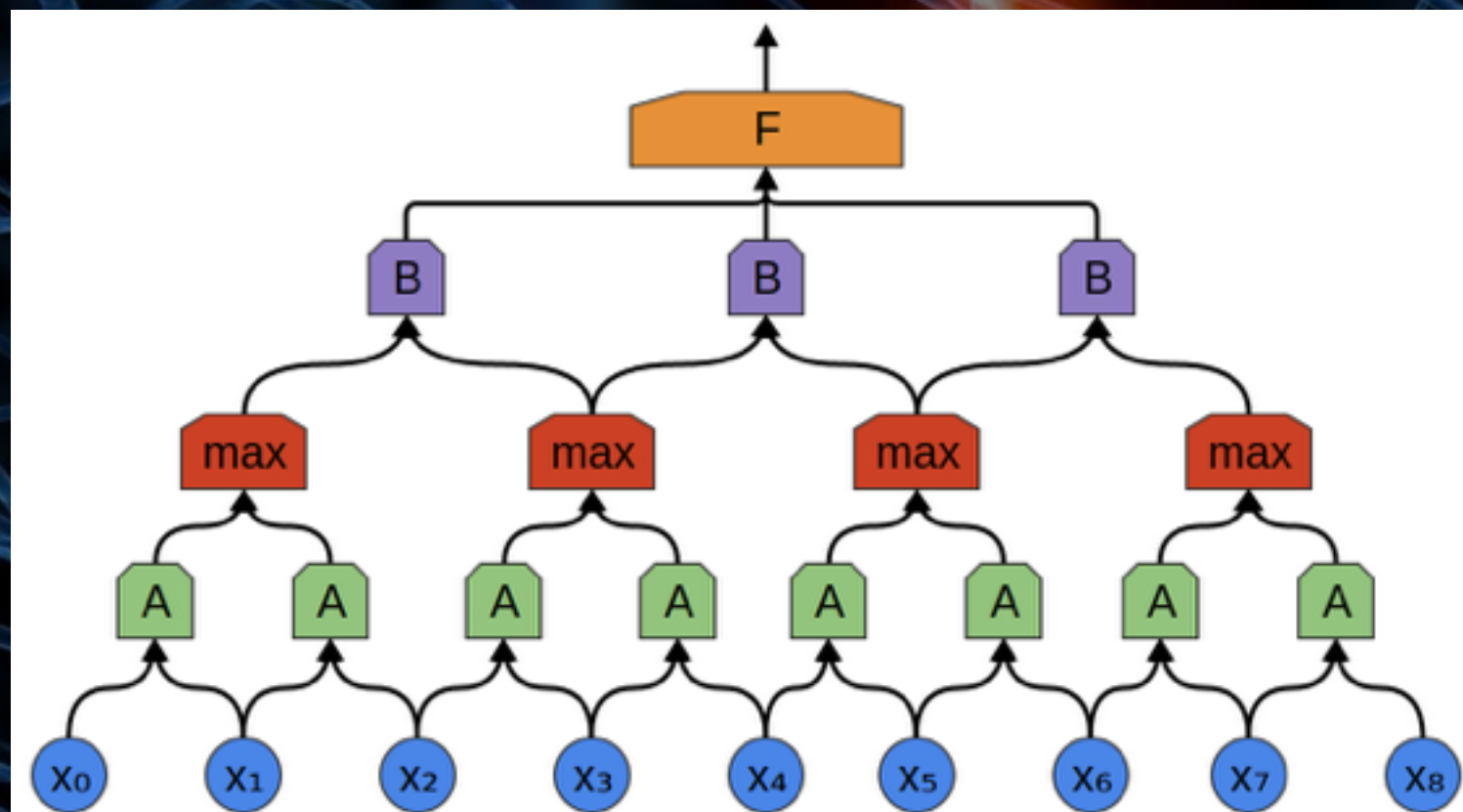
Convolutional Neural Networks

Convolutional Neural Networks

ConvNets are designed to process data that come in the form of multiple arrays (e.g. a color image composed of three 2D arrays with pixel intensities in the three color channels).

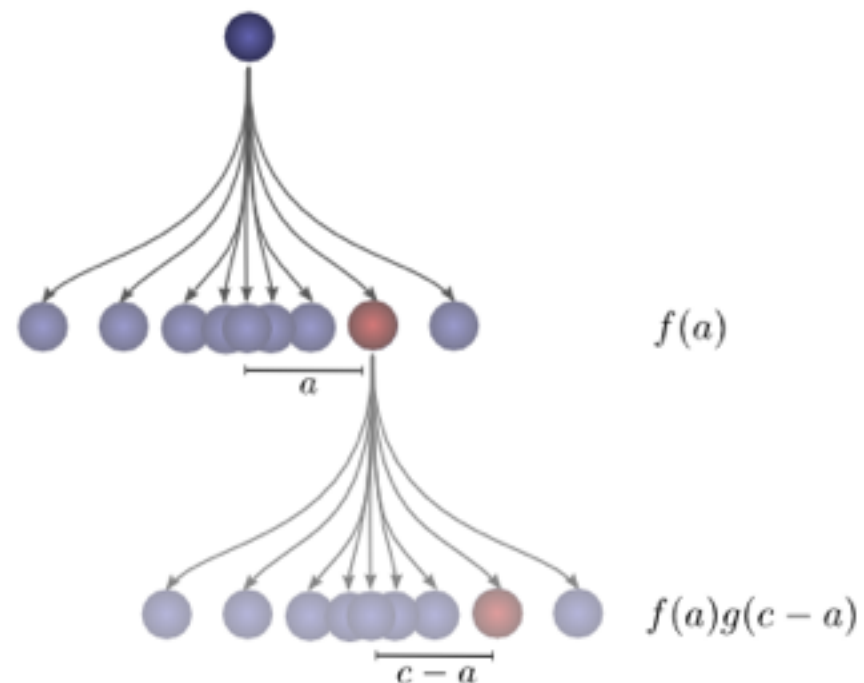
Key ideas behind ConvNets that take advantage of the properties of natural signals: local connections, shared weights, pooling and the use of many layers.

Convolutional Neural Networks

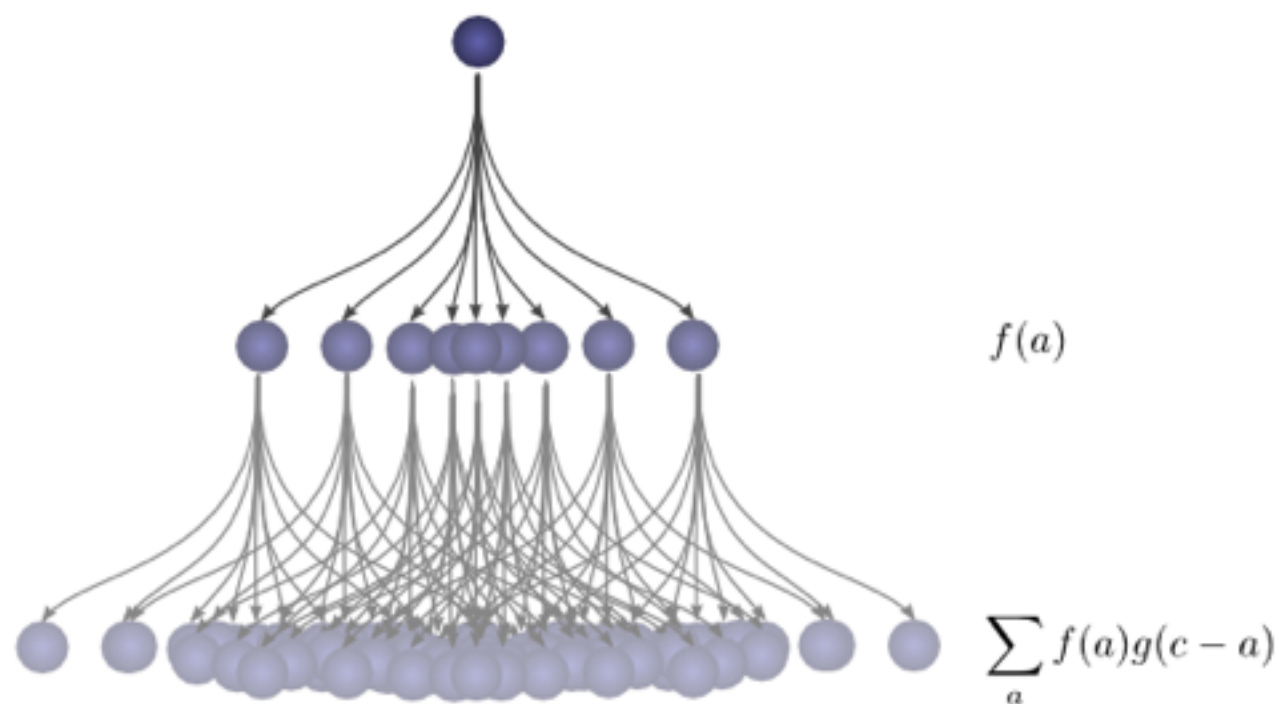


Lin, M., Chen, Q., Yan, S.
Network In Network

Convolutions



$$(f * g)(c) = \sum_a f(a) \cdot g(c - a)$$



$$(f * g)(c) = \sum_{a+b=c} f(a) \cdot f(b)$$

<http://colah.github.io/posts/2014-07-Understanding-Convolutions/>

The background is a dark blue field filled with a complex, tangled web of thin, glowing blue lines that resemble neural connections or data pathways. Several bright, glowing orange-yellow nodes are scattered throughout the network, with one prominent node located near the center of the image, directly behind the text.

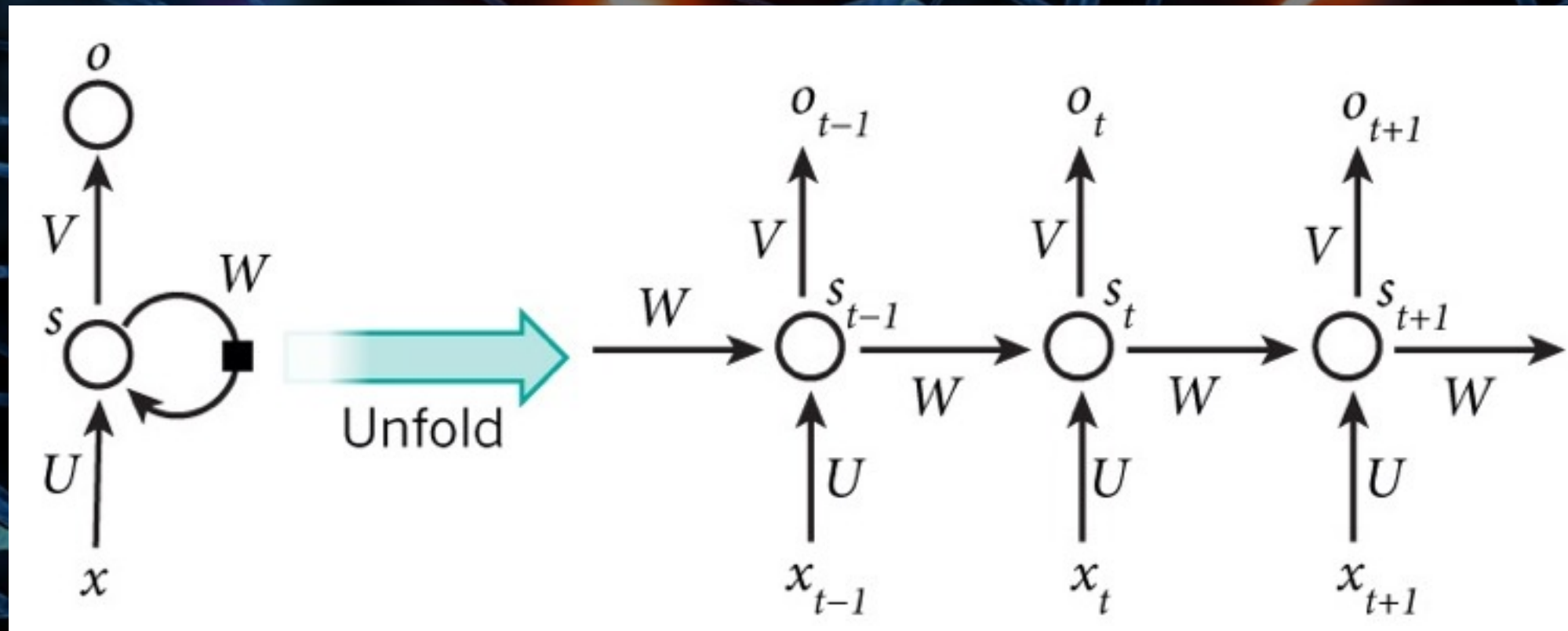
Recurrent Neural Networks

Recurrent Neural Networks

RNNs process an input sequence one element at a time, maintaining in their hidden units a 'state vector' that implicitly contains information about the history of all the past elements of the sequence.

Consider the outputs of the hidden units at different discrete time steps as if they were the outputs of different neurons in a deep multilayer network .

Recurrent Neural Networks



$$s_t = f(Ux_t + Ws_{t-1})$$

The background is a dark blue field filled with a dense, chaotic network of thin, glowing blue lines that resemble neural connections or data pathways. Several bright orange-yellow points of light are scattered throughout, appearing as if they are sparks or energy sources at the intersections of the blue lines. A single, slightly larger, translucent purple sphere is positioned near the center of the image, partially obscured by the blue lines.

The Future of Deep Learning

The Future of Deep Learning

Scattering transform: Bruna, J., Mallat, S., *Invariant Scattering Convolution Networks*

Complex-valued ConvNets: Tygert, M, et al., *A theoretical argument for complex-valued convolutional networks*

Renormalization: Mehta, P., Schwab, D.J., *An exact mapping between the Variational Renormalization Group and Deep Learning*

The Future of Deep Learning

Unsupervised learning: Human and animal learning is largely unsupervised. We discover the structure of the world by observing it, not by being told the name of every object.

Memory: Proposals include the Neural Turing Machine in which the network is augmented by a 'tape-like' memory, and memory networks, in which a regular network is augmented by a kind of associative memory.

Reasoning: Ultimately, major progress in artificial intelligence will come about through systems that combine representation learning with complex reasoning. New paradigms are needed to replace rule-based manipulation of symbolic expressions by operations on large vectors.

Resources

<http://jmozah.github.io/links/>

<http://www.thetalkingmachines.com/blog/>

<http://www.docdroid.net/11p1b/hinton.pdf.html>

<http://deeplearning.net/tutorial/contents.html>

<http://karpathy.github.io/2015/05/21/rnn-effectiveness/>

<https://drive.google.com/file/d/0BxKBnD5y2M8NbWN6XzM5UXkwNDA/view?pli=1>

http://blog.shakirm.com/wp-content/uploads/2015/10/Bayes_Deep.pdf

<https://www.quantamagazine.org/20141204-a-common-logic-to-seeing-cats-and-cosmos/>

The background is a dark blue field filled with a dense, chaotic network of thin, glowing blue lines that resemble a complex web or a neural network. Several bright orange-yellow points of light are scattered throughout, some appearing as small, star-like bursts and others as elongated, comet-like streaks. In the center of the image, there is a faint, translucent blue shape that looks like a cell or a small organism, with a solid purple sphere positioned just below the 'Q&A' text.

Q&A

Questions?

Thank You



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