

The background features a complex, abstract pattern of glowing blue and red lines and shapes, resembling a network or a biological structure, set against a dark background.

Tools and Algorithms

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December 7, 2021

Tools and Algorithms

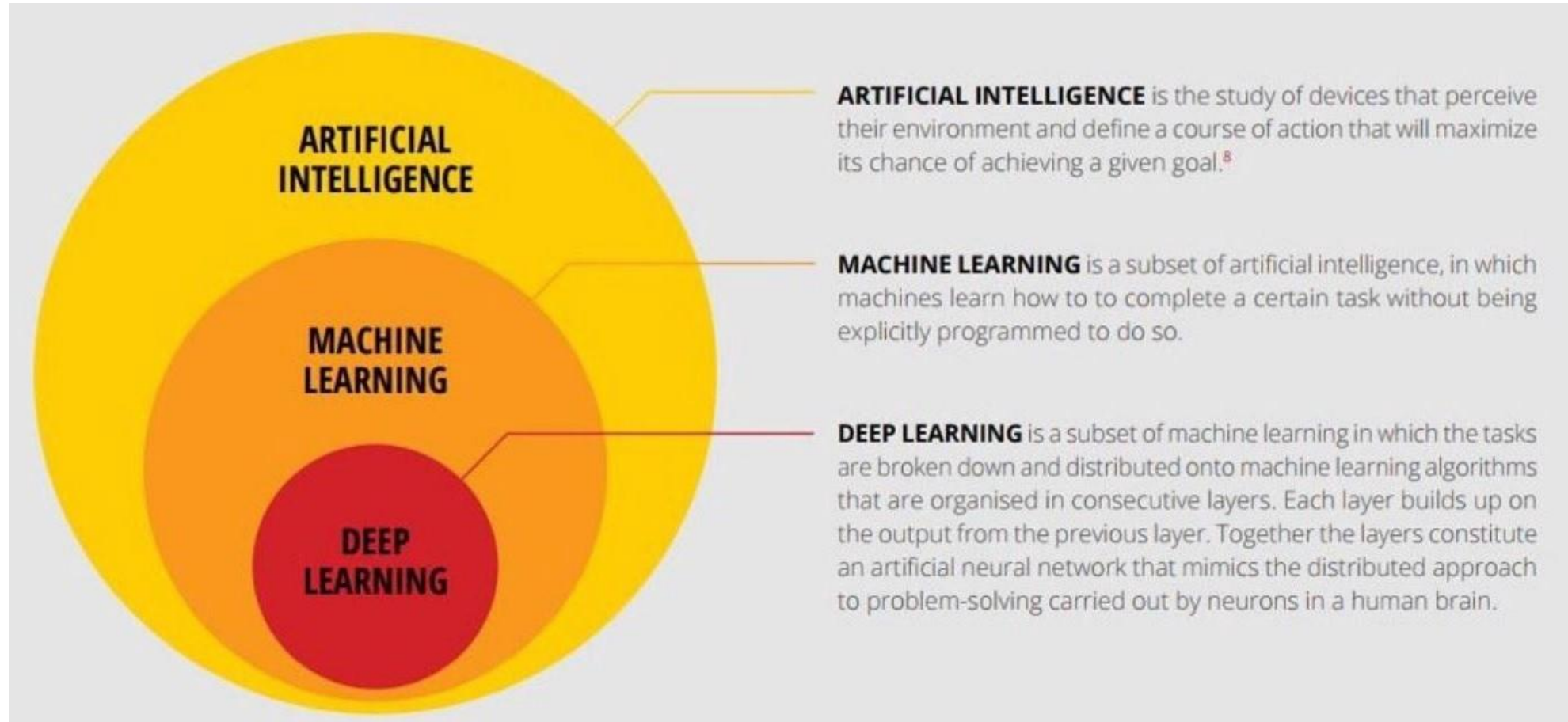
Developers cannot just ask, “What do I need to do to fix my algorithm?” They must rather ask: “How does my algorithm interact with society at large, and as it currently is, including its structural inequalities?” (Zimmerman, et.al., 2020)

```
19  template<...>
20  unsigned int levenshtein(const string& s1, const string& s2) {
21      const size_t len1 = s1.size(), len2 = s2.size();
22      vector<unsigned int> col(len2+1), prevCol(len2+1);
23      for (unsigned int i = 0; i < prevCol.size(); i++)
24          prevCol[i] = i;
25      for (unsigned int i = 0; i < len1; i++) {
26          col[0] = i+1;
27          for (unsigned int j = 0; j < len2; j++)
28              col[j+1] = std::min( std::min(prevCol[i + j] + 1, col[j] +
29                                          prevCol[j] + (s1[i]==s2[j] ? 0 : 1) ));
30          col.swap(prevCol);
31      }
32      return prevCol[len2];
33  }
```

Title Image: <https://ethicstoolkit.ai/>

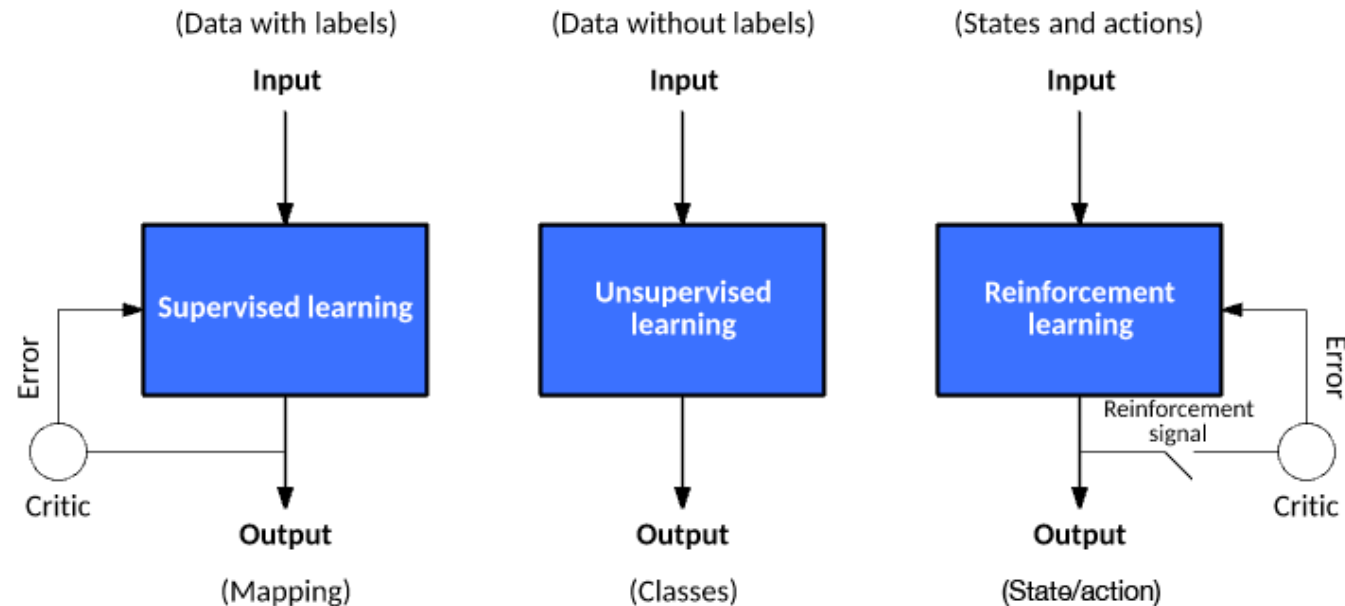
<https://www.pewresearch.org/internet/2017/02/08/code-dependent-pros-and-cons-of-the-algorithm-age/>

Artificial Intelligence



Types of Machine Learning

- **Supervised**
 - Uses labeled datasets to train algorithms
- **Unsupervised**
 - Discover hidden patterns in unlabeled data without human intervention
- **Reinforcement**
 - Applied within a context and uses environment states as input

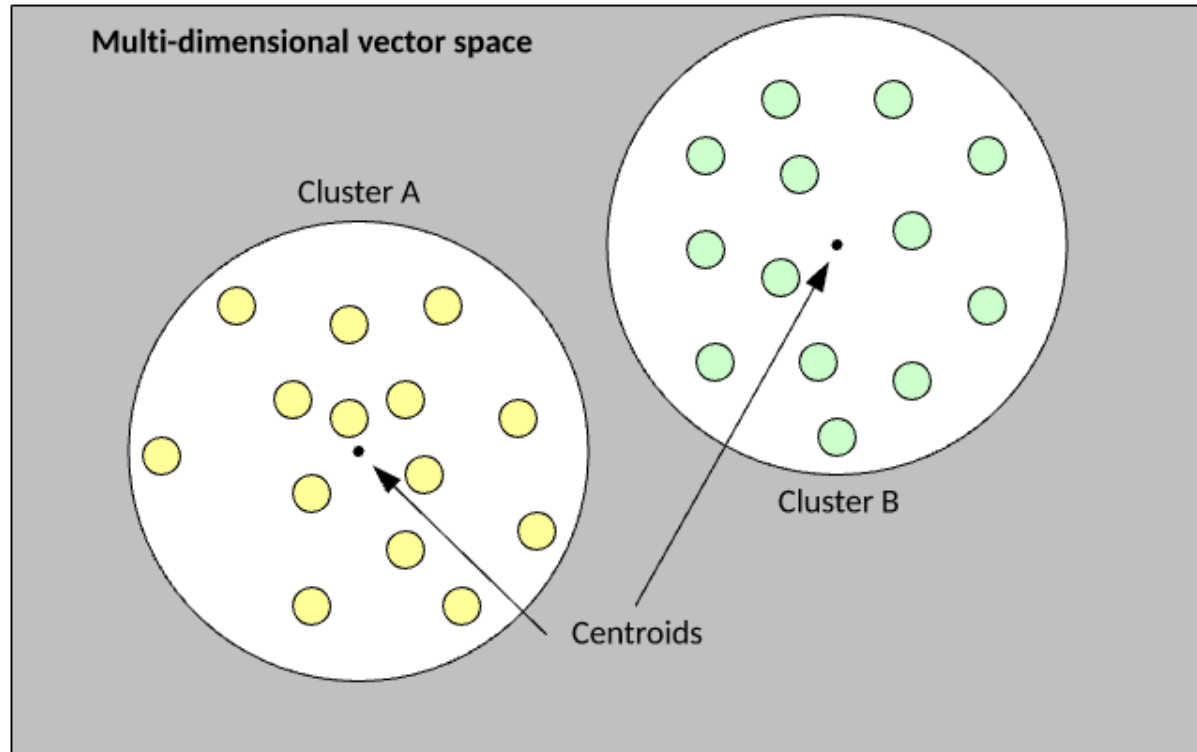


<https://www.ibm.com/cloud/learn/supervised-learning>

<https://www.ibm.com/cloud/learn/unsupervised-learning>

<https://developer.ibm.com/articles/cc-models-machine-learning/#reinforcement-learning>

K-Means Clustering



- This is an example of an unsupervised algorithm
- “The goal of the algorithm is to partition examples from a data set into k clusters. Each example is a numerical vector that allows the distance between vectors to be calculated as a Euclidean distance.”

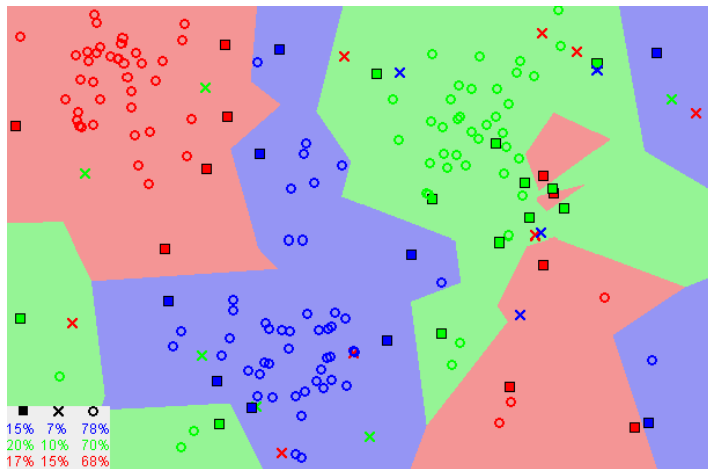
<https://developer.ibm.com/articles/cc-models-machine-learning/#reinforcement-learning>

<https://towardsdatascience.com/understanding-k-means-clustering-in-machine-learning-6a6e67336aa1>

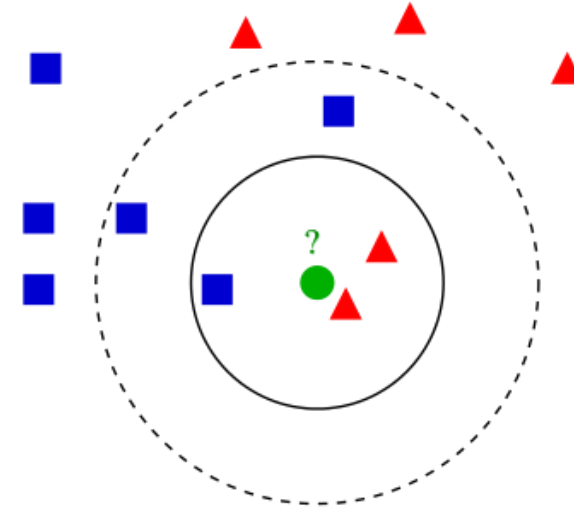
<https://www.analyticsvidhya.com/blog/2019/08/comprehensive-guide-k-means-clustering/>

K-Nearest Neighbors

Clusters data into groups based on similarity or proximity

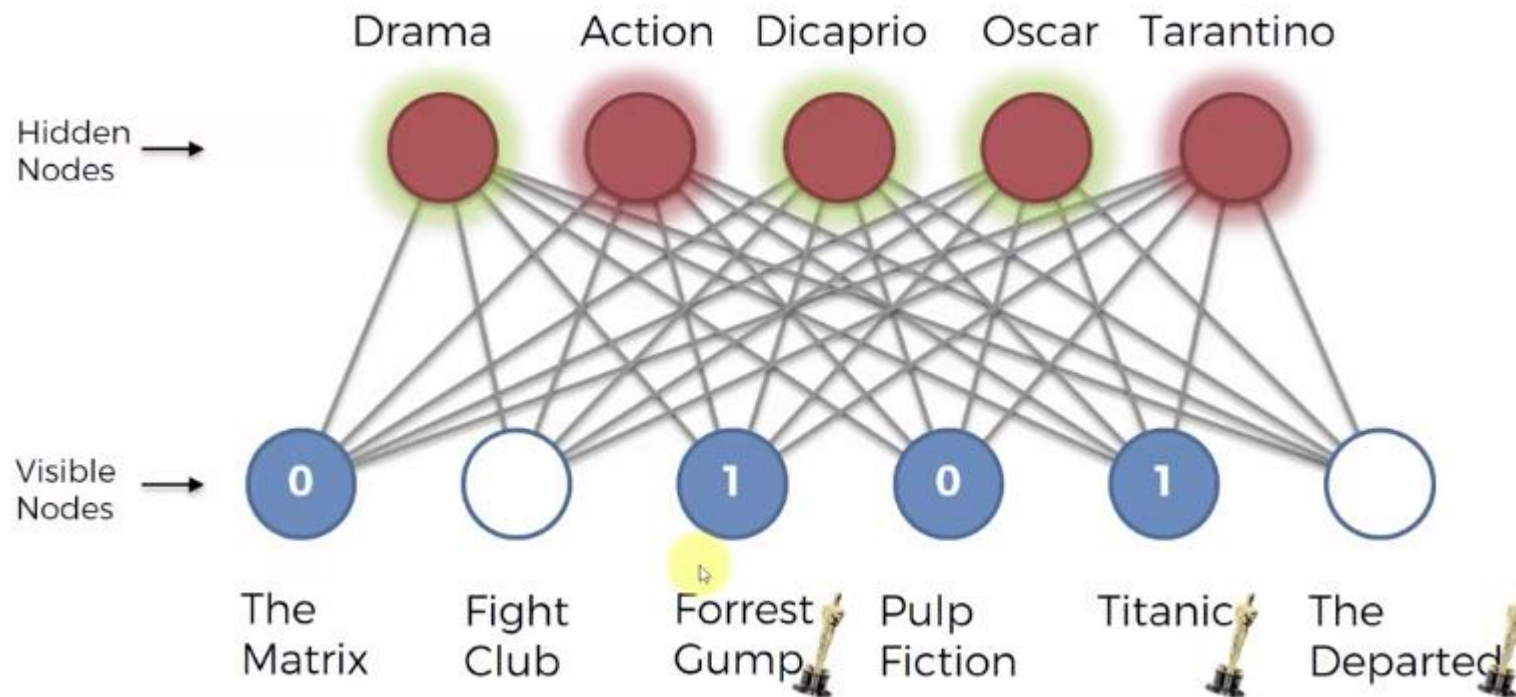


<https://www.codecademy.com/learn/introduction-to-supervised-learning-skill-path/modules/k-nearest-neighbors-skill-path/cheatsheet>
https://en.wikipedia.org/wiki/K-nearest_neighbors_algorithm



Example of k -NN classification. The test sample (green dot) should be classified either to blue squares or to red triangles. If $k = 3$ (solid line circle) it is assigned to the red triangles because there are 2 triangles and only 1 square inside the inner circle. If $k = 5$ (dashed line circle) it is assigned to the blue squares (3 squares vs. 2 triangles inside the outer circle).

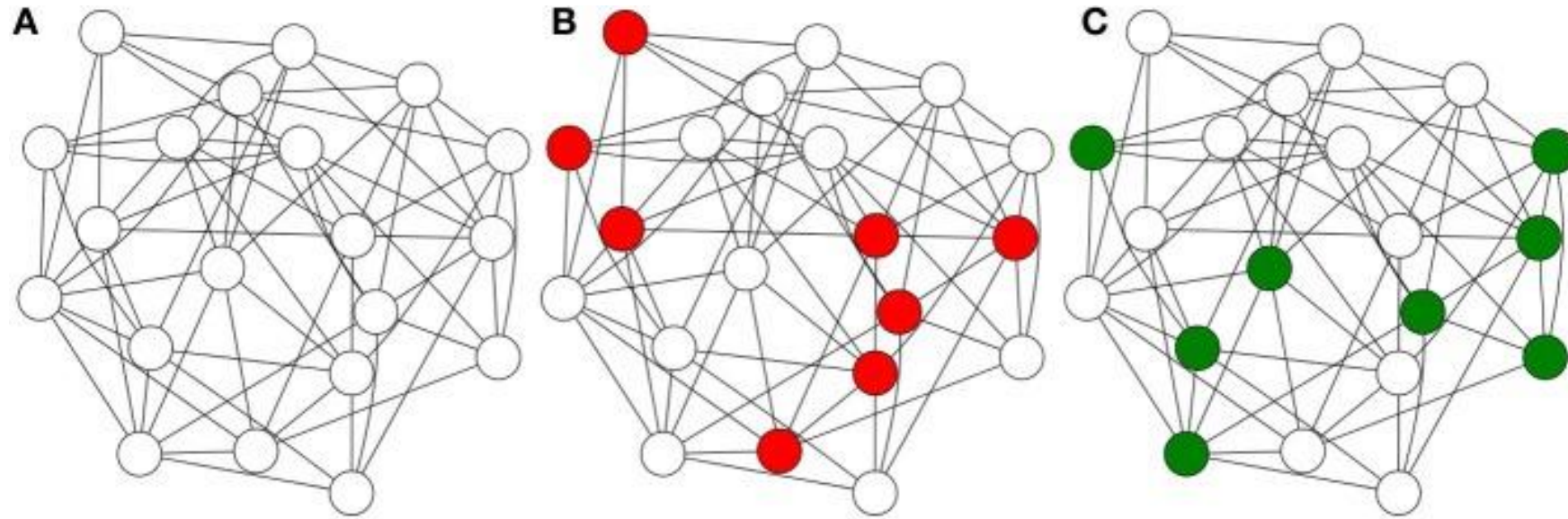
Learning Algorithms



A learning algorithm is a method or system used to update the weights between connections

Image: <https://demyank.tistory.com/351>

Hebbian Learning



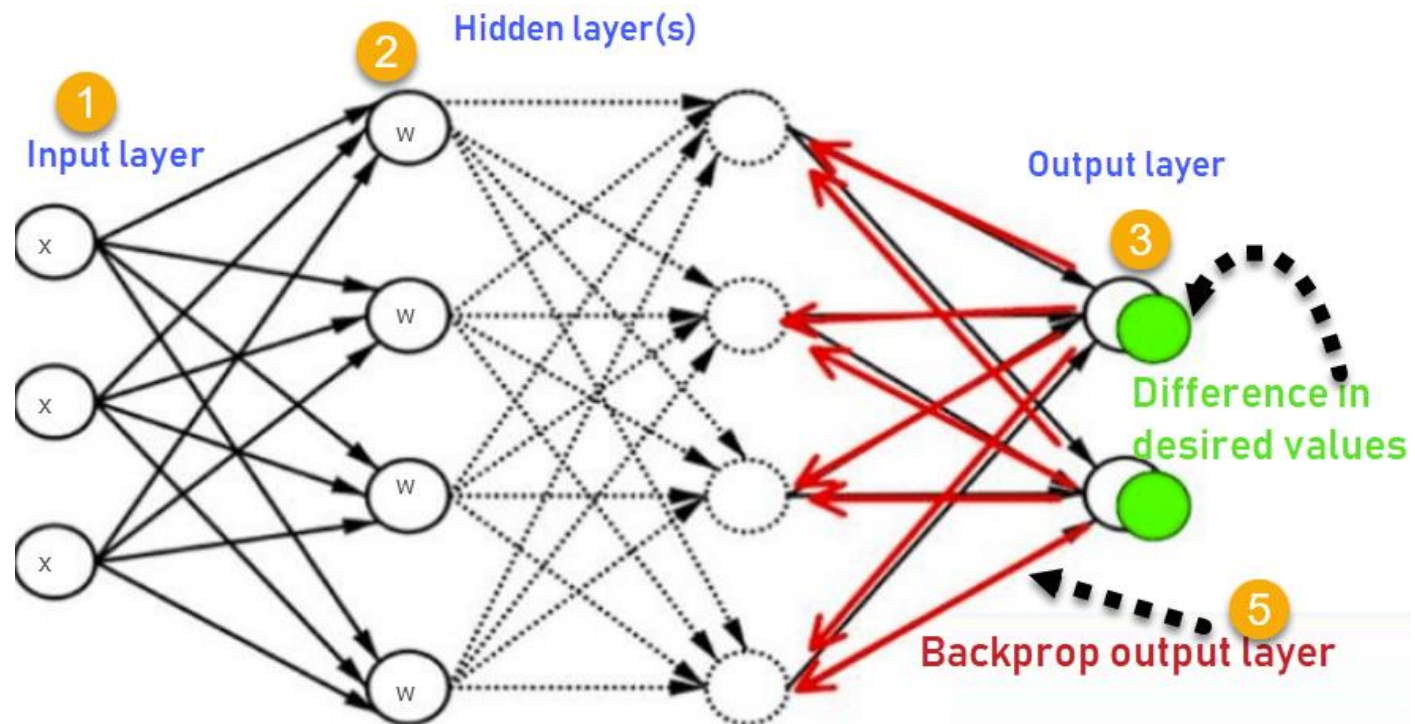
Often summarized as "Cells that fire together wire together."

https://en.wikipedia.org/wiki/Hebbian_theory

[Image:https://www.researchgate.net/publication/262150025_Sparse_Distributed_Memory_understanding_the_speed_and_robustness_of_expert_memory](https://www.researchgate.net/publication/262150025_Sparse_Distributed_Memory_understanding_the_speed_and_robustness_of_expert_memory)

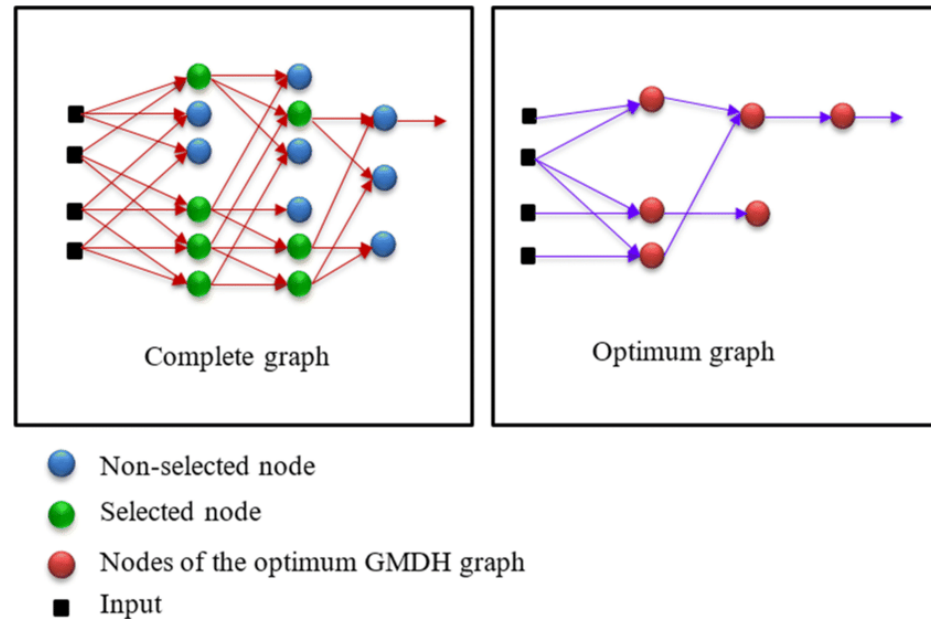
Backpropagation

- Described previously (<https://ethics.mooc.ca/presentation/59>)
- Errors are measured and correction sent back through the network



Group Method of Data Handling (GMDH)

“The algorithm develops neurons for all possible combinations of two inputs to the layer. It then continues to choose only those neurons that supply the best possible MSE.”

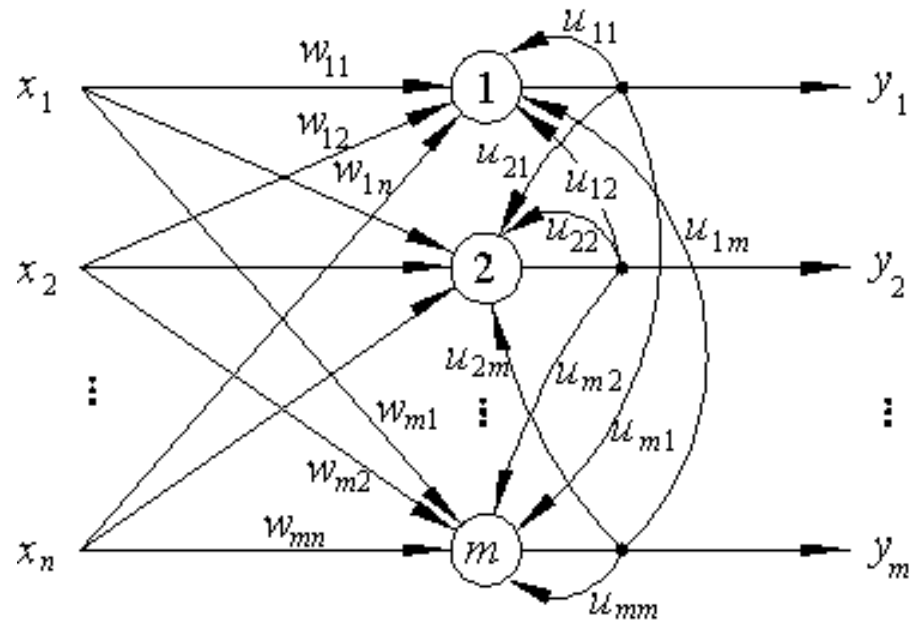


https://en.wikipedia.org/wiki/Group_method_of_data_handling

<http://www.gmdh.net/>

[https://www.researchgate.net/publication/315684693 Neural Network Training Using a GMDH Type Algorithm](https://www.researchgate.net/publication/315684693_Neural_Network_Training_Using_a_GMDH_Type_Algorithm)

Competitive Learning



“Nodes compete for the right to respond to a subset of the input data. The individual neurons of the network learn to specialize on ensembles of similar patterns and in so doing become 'feature detectors' for different classes of input patterns.”

https://neuron.eng.wayne.edu/tarek/MITbook/chap3/3_4.html

<https://archive.org/details/paralleldistribu00rume/page/151/mode/2up>

https://en.wikipedia.org/wiki/Competitive_learning

Neuroevolution

Evolutionary algorithms generate neural networks, parameters, topology and rules.

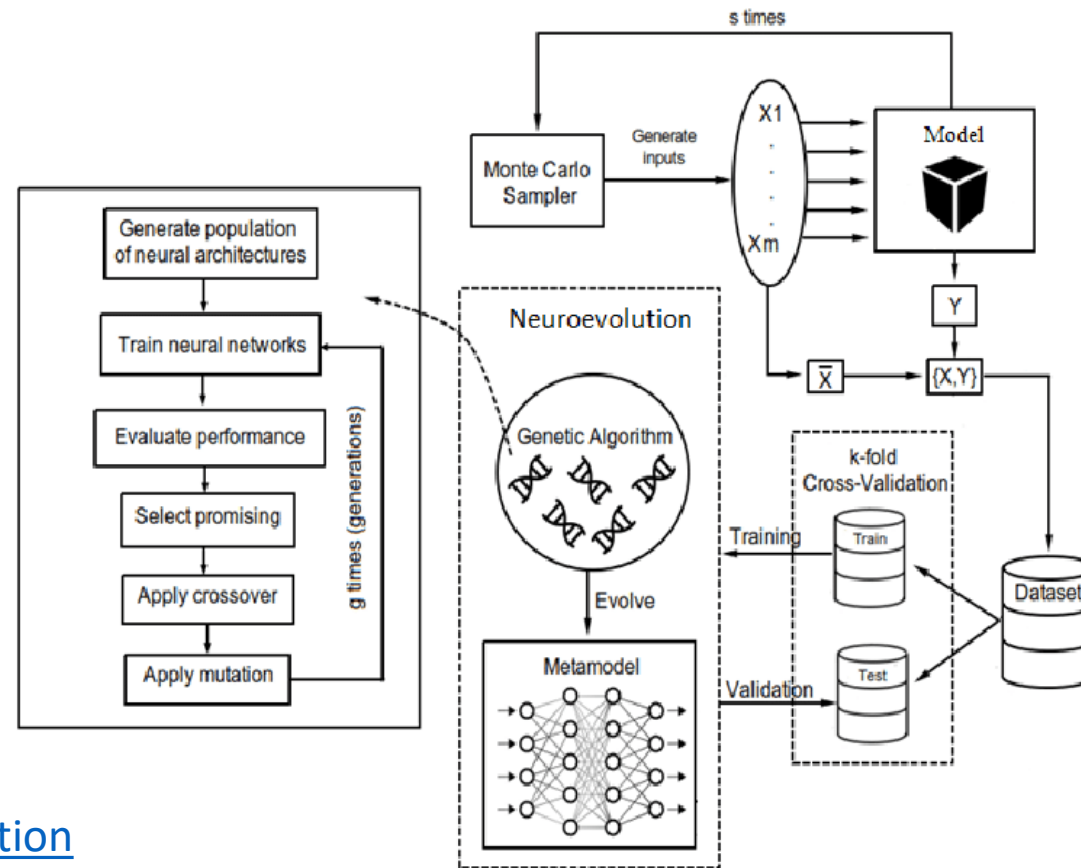
https://www.researchgate.net/publication/349150012_Neuroevolutionary_Approach_to_Metamodel-Based_Optimization_in_Production_and_Logistics

<https://en.wikipedia.org/wiki/Neuroevolution>

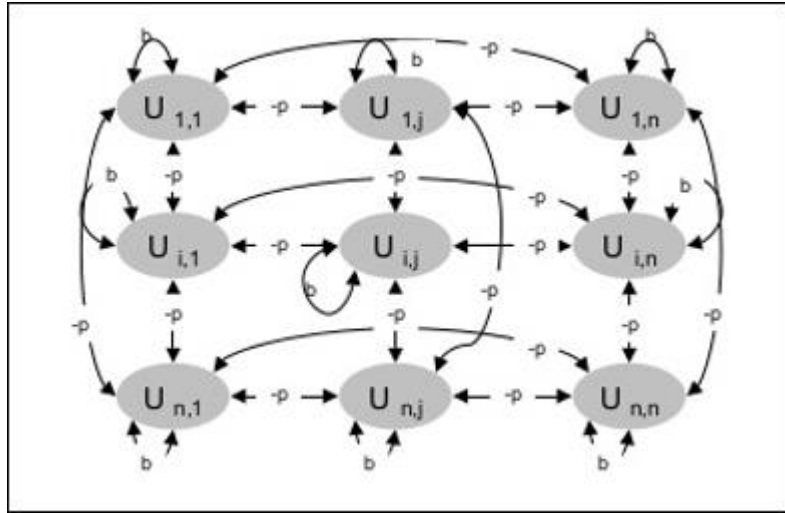
<https://www.nature.com/articles/s42256-018-0006-z>

<https://towardsdatascience.com/a-primer-on-the-fundamental-concepts-of-neuroevolution-9068f532f7f7>

Vid: <https://www.youtube.com/watch?v=lu5ul7z4icQ>



Restricted Boltzmann Machine



“While RBMs are occasionally used, most practitioners in the machine-learning community have deprecated them in favor of generative adversarial networks or variational autoencoders. RBMs are the Model T’s of neural networks – interesting for historical reasons, but surpassed by more up-to-date models.”

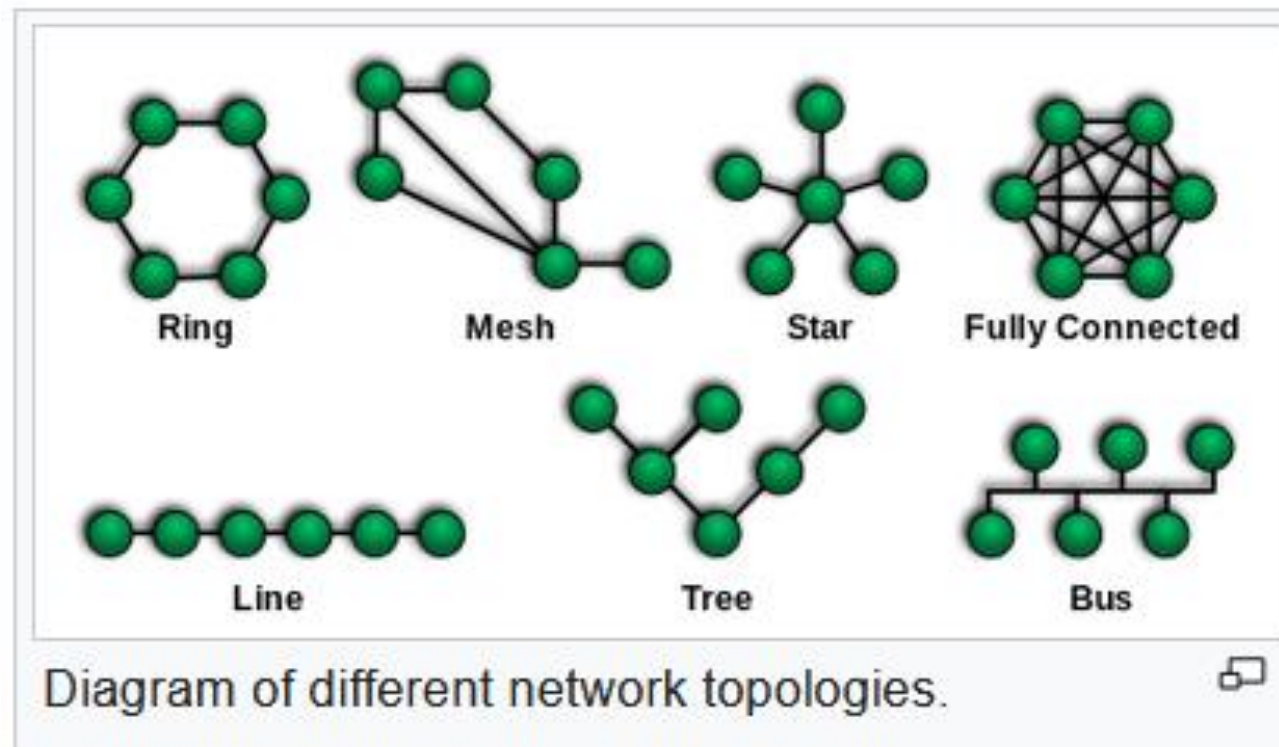
<https://wiki.pathmind.com/restricted-boltzmann-machine>

https://www.tutorialspoint.com/artificial_neural_network/artificial_neural_network_boltzmann_machine.htm

Network Topology

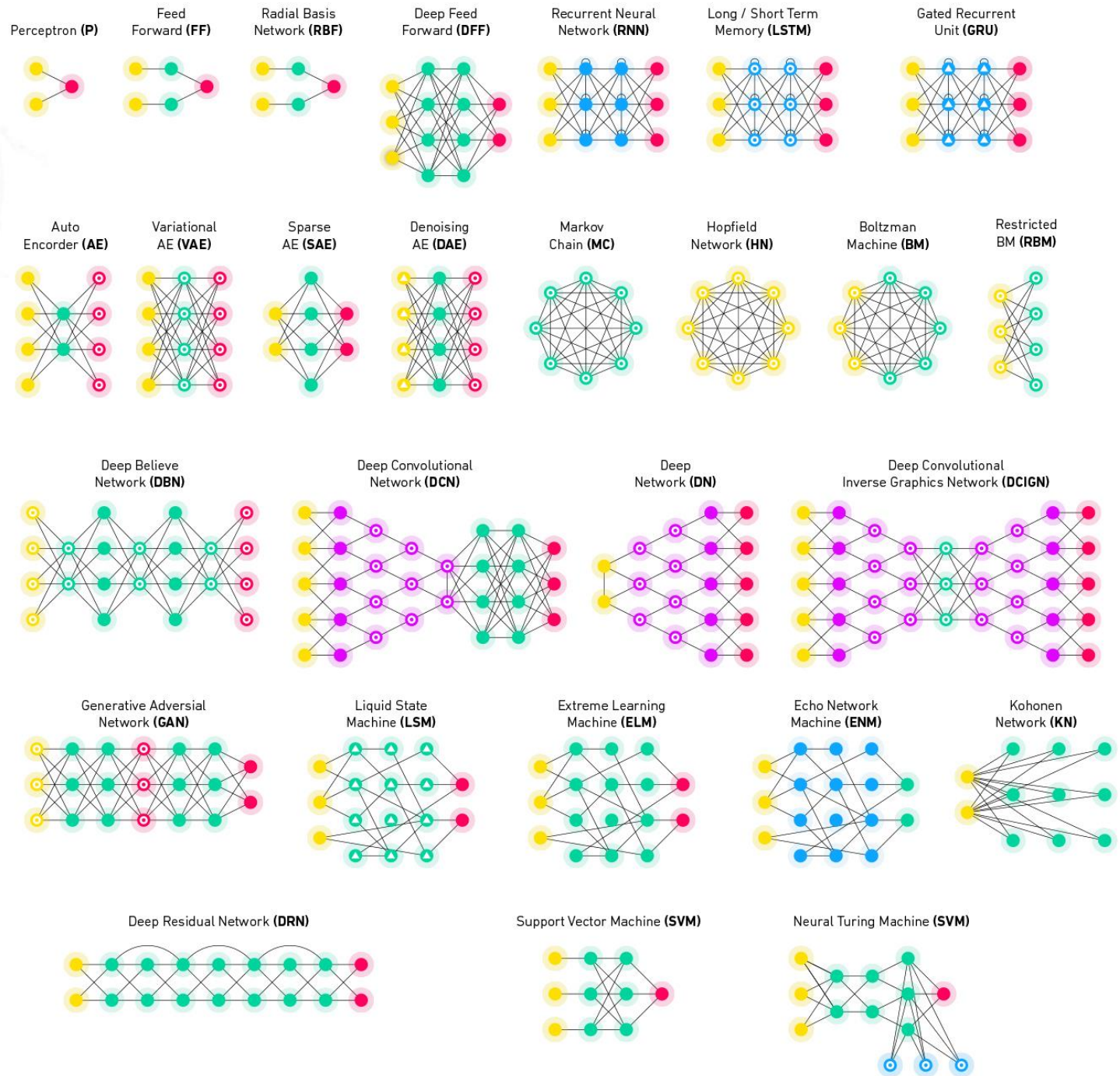
- Physical topology is the placement of network components
- Logical topology shows how data flows within a network

https://en.wikipedia.org/wiki/Network_topology



Topologies

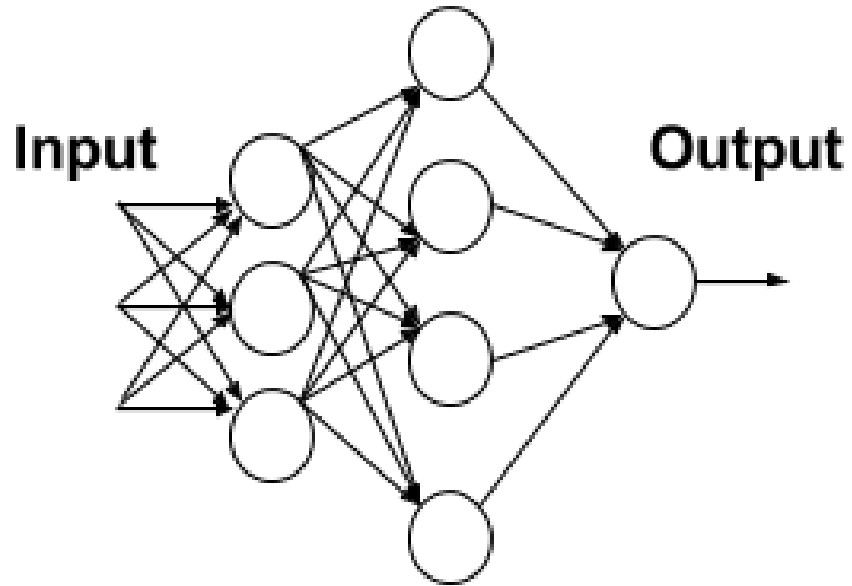
There is a rich array of machine learning and AI designs. We'll look at only a few classic ones in this presentation.



<https://docs.paperspace.com/machine-learning/wiki/machine-learning-models-explained>

Feedforward Neural Networks

- Example: the perceptron and multi-layer perceptron
- Data flows from input to output (ie., it feeds forward)

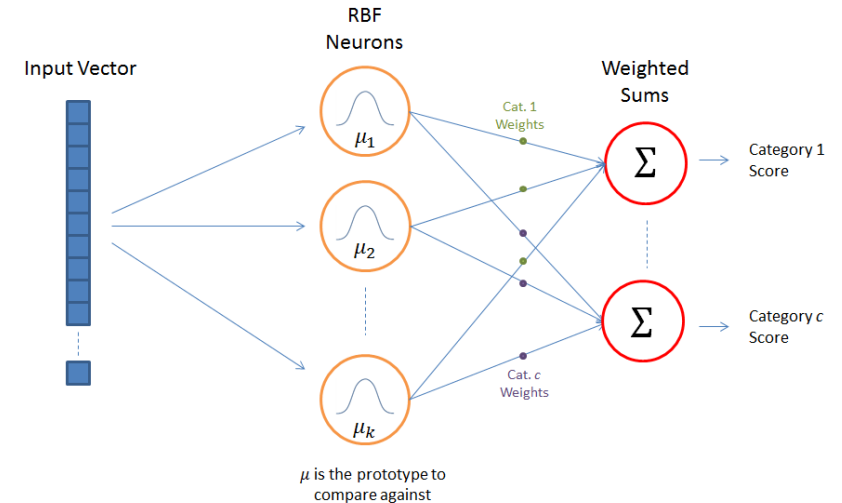
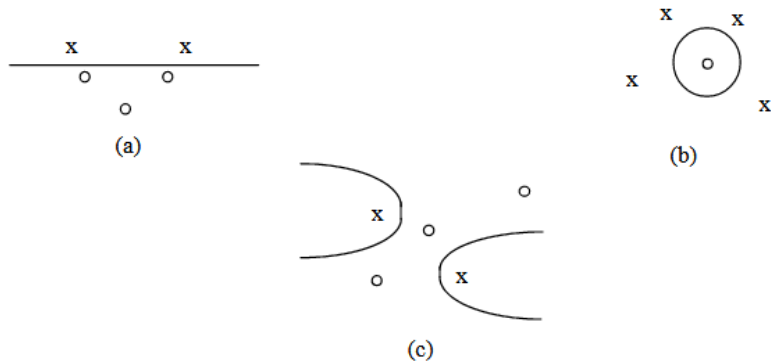


https://en.wikipedia.org/wiki/Feedforward_neural_network

<https://towardsdatascience.com/deep-learning-feedforward-neural-network-26a6705dbdc7>

Radial Basis Networks

- Radial Basis Function network was formulated by Broomhead and Lowe in 1988.
- These are non-linear classifiers (ie., they draw circles in data).



<https://vtechworks.lib.vt.edu/bitstream/handle/10919/36847/Ch3.pdf?sequence=5>

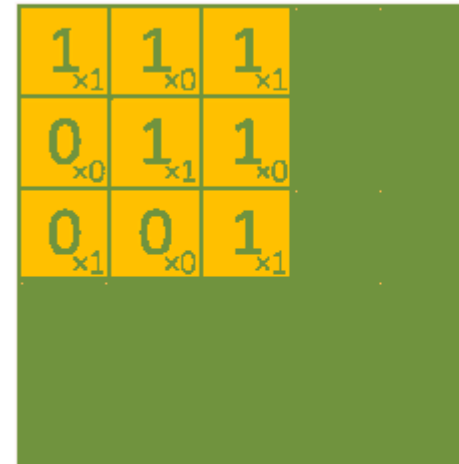
<https://www.cc.gatech.edu/~isbell/tutorials/rbf-intro.pdf>

Convolutional Neural Network

A CNN samples different parts of the input data using a filter. These filters can be thought of as feature detectors.

The convolution layer is usually followed with a pooling layer, which reduces the overall size of the matrix. It is then fed into (e.g.) a perceptron.

<https://towardsdatascience.com/a-comprehensive-guide-to-convolutional-neural-networks-the-eli5-way-3bd2b1164a53>



Image



Convolved Feature

Convoluting a 5x5x1 image with a 3x3x1 kernel to get a 3x3x1 convolved feature

Kernel/Filter, K =

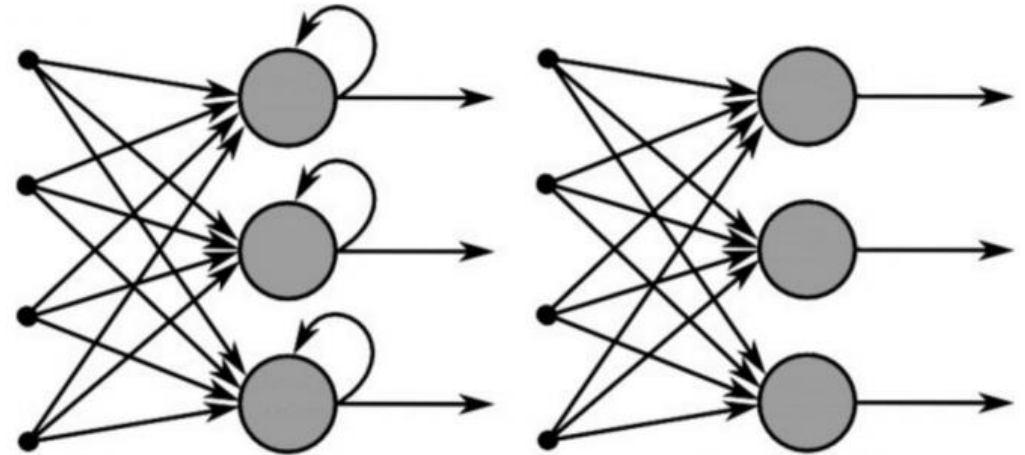
```
1 0 1
0 1 0
1 0 1
```

Recurrent Neural Networks

In RNNs the output from one neuron becomes the input for other neurons.

Fully recurrent neural networks (FRNN) connect all neurons to each other.

In simple recurrent networks (SRN) context units feed back into other units in a 3-layer network.



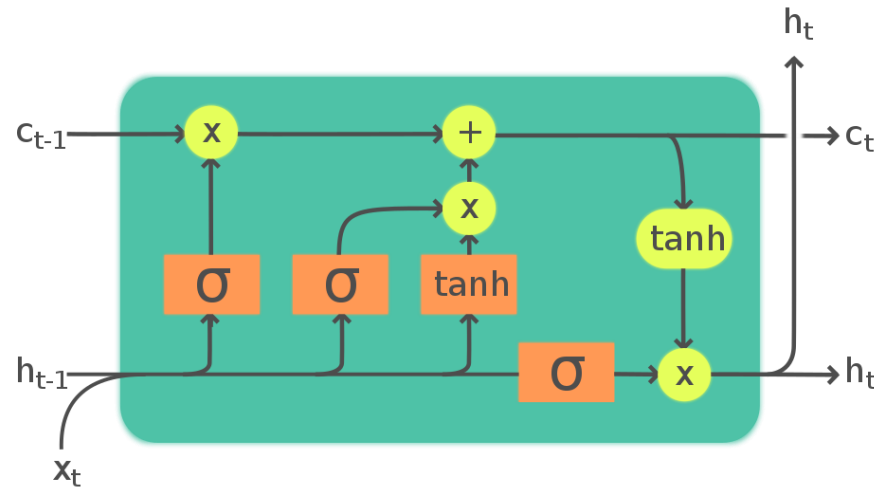
Recurrent Neural Network

Feed-Forward Neural Network

https://en.wikipedia.org/wiki/Recurrent_neural_network

<https://builtin.com/data-science/recurrent-neural-networks-and-lstm>

Long short-term memory (LSTM)



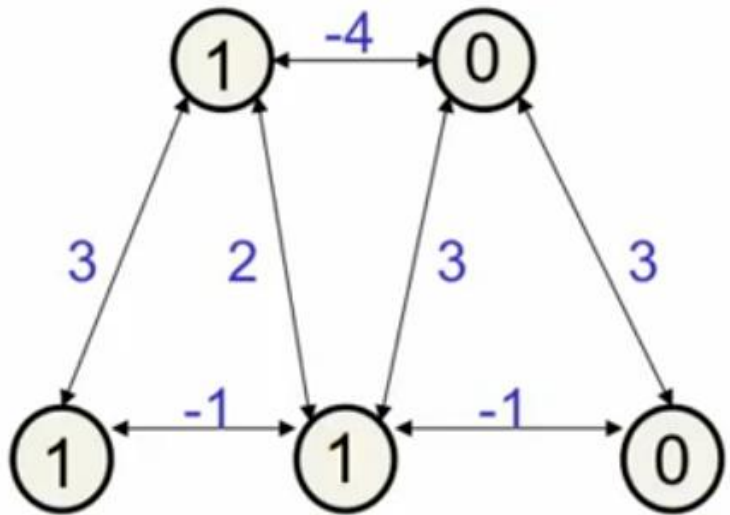
Legend: Layer Componentwise Copy Concatenate

Orange rectangle: Layer
Yellow circle: Componentwise Copy
Upward arrow: Copy
Downward arrow: Concatenate

“The Long Short-Term Memory (LSTM) cell can process data sequentially and keep its hidden state through time... LSTM is applicable to tasks such as unsegmented, connected handwriting recognition, speech recognition and anomaly detection”

https://en.wikipedia.org/wiki/Long_short-term_memory

Hopfield Networks



$$-E = \text{goodness} = 4$$

Hopfield (1982): memories could be energy minima of a neural net. “The purpose of a Hopfield net is to store 1 or more patterns and to recall the full patterns based on partial input.”

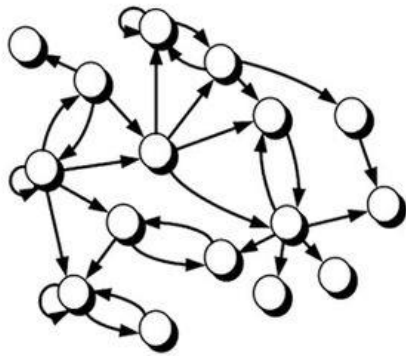
<https://towardsdatascience.com/hopfield-networks-are-useless-heres-why-you-should-learn-them-f0930ebeadcd>

Vid: <https://www.youtube.com/watch?v=DS6k0PhBjpl>

Attractor Networks

“An attractor network is a type of recurrent dynamical network that evolves toward a stable pattern over time”

Complex regulatory network
(p53 regulatory network)

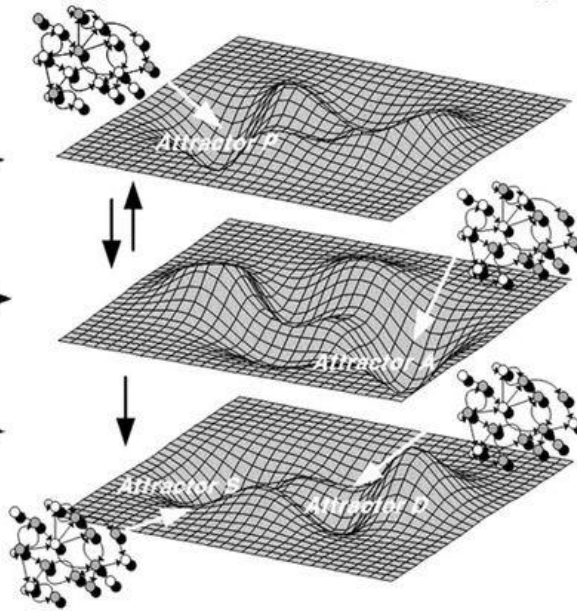


No
DNA damage

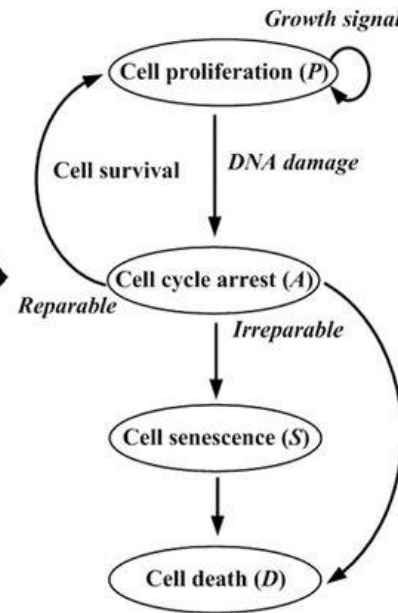
Reparable
DNA damage

Irreparable
DNA damage

Dynamic attractor landscape

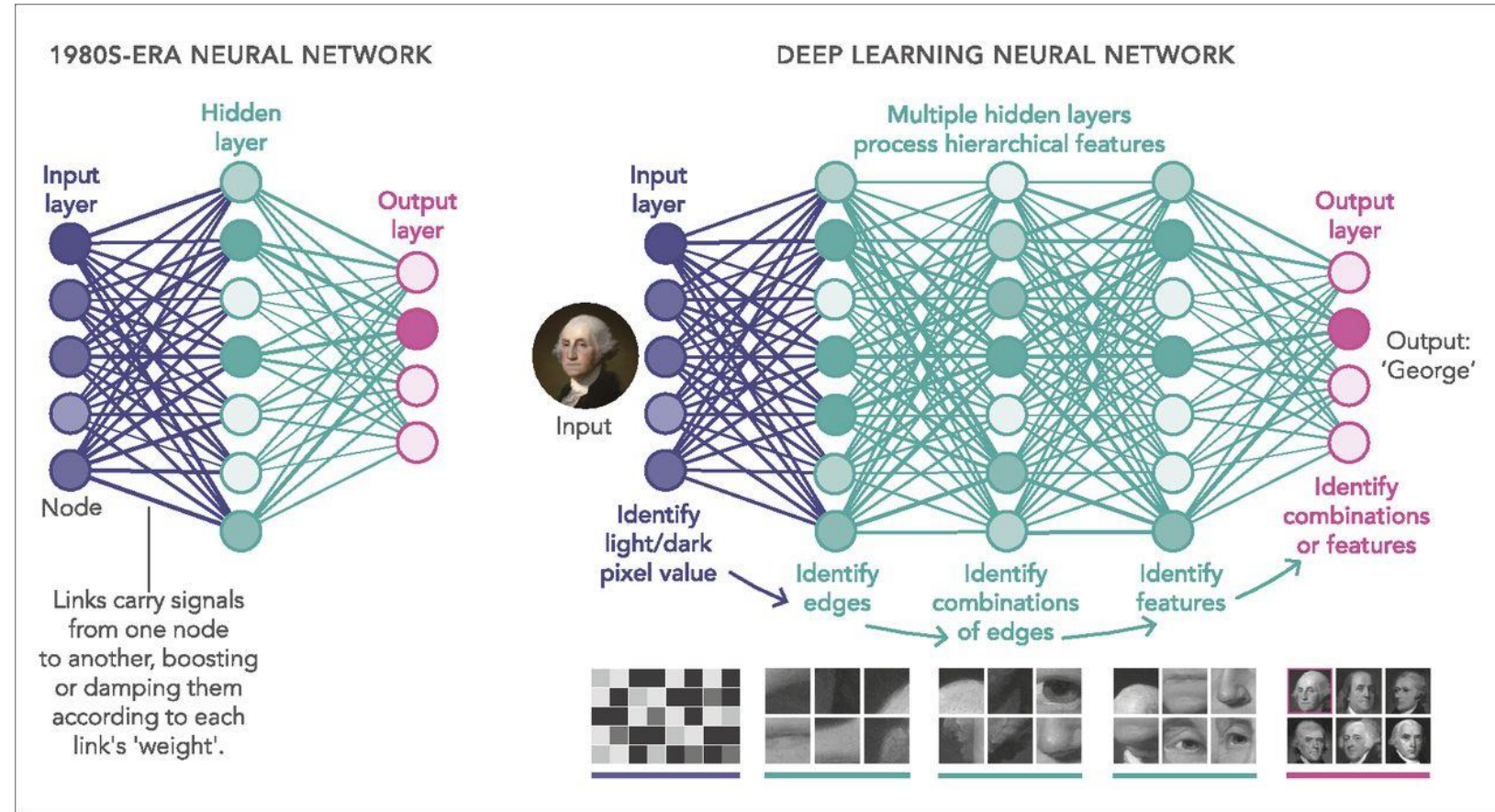


Cellular state transition



Deep Learning

Deep learning is a term used to describe neural networks with multiple hidden layers (hence, 'deep')



Frameworks

- [Scikit Learn](#)
- [TensorFlow](#)
- [Theano](#)
- [Caffe](#)
- [MxNet](#)
- [Keras](#)
- [PyTorch](#)
- [CNTK](#)
- [Auto ML](#)
- [OpenNN](#)
- [Google ML Kit](#)

