Biologically Inspired Computation

Dr Marta Vallejo

m.vallejo@hw.ac.uk

Content of the Course

1.- Neural computation (gradient descent, multilayer perceptron, recurrent neural networks, deep learning)

2.- Evolutionary algorithms (basic EA design, multi-objective optimisation, genetic programming)

3.- Swarm intelligence (ant colony methods, particle swarm optimisation)

4.- Cellular automata

5.- Gene Regulatory Models

Assessment

Examination: (weighting – 50%)

Coursework: (weighting – 50%)

Two courseworks, one per each part of the course (weighting – 25% each). In my part:

- Coursework 1a: Gradient Descent (5%)
- Coursework 1b: Artificial Neural Network & Deep Learning (20%)

Timetable

Week	Lecture 1 (Tuesday 16:15)	Lecture 2 (Wednesday 10:15)	Coursework
1	Intro to bio-inspired computing and artificial neural networks	Basic concepts and gradient descent algorithm	**CW1a (5%) out - Wednesday**
2	Reading week		
3	Back Propagation	Recurrent Neural Networks & Intro to Deep Learning	**CW1a in - Wednesday** **CW1b (20%) out - Wednesday**
4	Deep Learning I	Deep Learning II	
5	Introduction to Evolutionary Algorithms	EA details, Encoding,Operators	
6	Hillclimbing, landscapes, neighbourhoods, local search	Neuroevolution	
7	Genetic programming I	Genetic programming II	**CW1 in - Monday** **CW2 (25%) out - Wednesday**
8	Swarm intelligence I	Swarm intelligence II	
9	Multi-objective EAs	Cellular automata	
10	Gene regulatory models		
11	Revision lecture (Part I)	Revision lecture (Part II)	**CW2 in - Thursday**
12	Revision period		

Lectures

- MV = Marta Vallejo, will generally lecture about bio-inspired methods for optimisation, with a focus on the basics and applications of evolutionary computation and neural computation – which underpins how we can build machines that learn from examples.

- ML = Michael Lones, will focus on 'advanced' bio-inspired optimisation methods, particularly genetic programming, and methods inspired by gene regulatory networks

How can you contact me?

Email:**m.vallejo@hw.ac.uk**

Office Location: EMG.42

Office Hours: Wednesdays from 11:30 am to 12:30pm

Personal Link: http://www.macs.hw.ac.uk/~mv59/

You could also arrange a meeting other days if you have further questions. Please, email me.

What is the most powerful problem solver in the Universe?

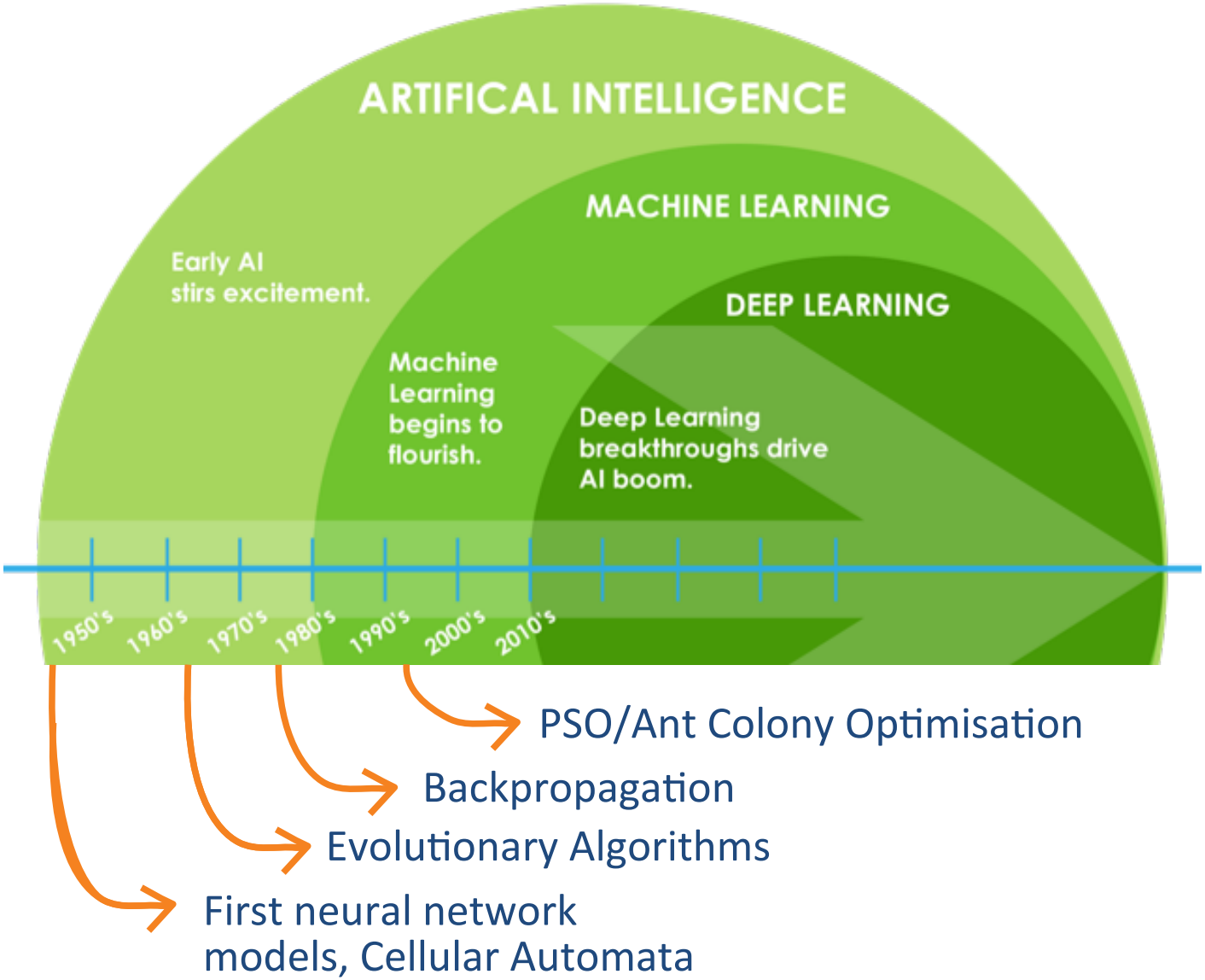
- The (human) brain
- The evolution mechanism...

  ...that created the human brain

Our goal is building problem solvers by looking at and mimicking:

- Brains: neurocomputing
- Evolution: evolutionary computation

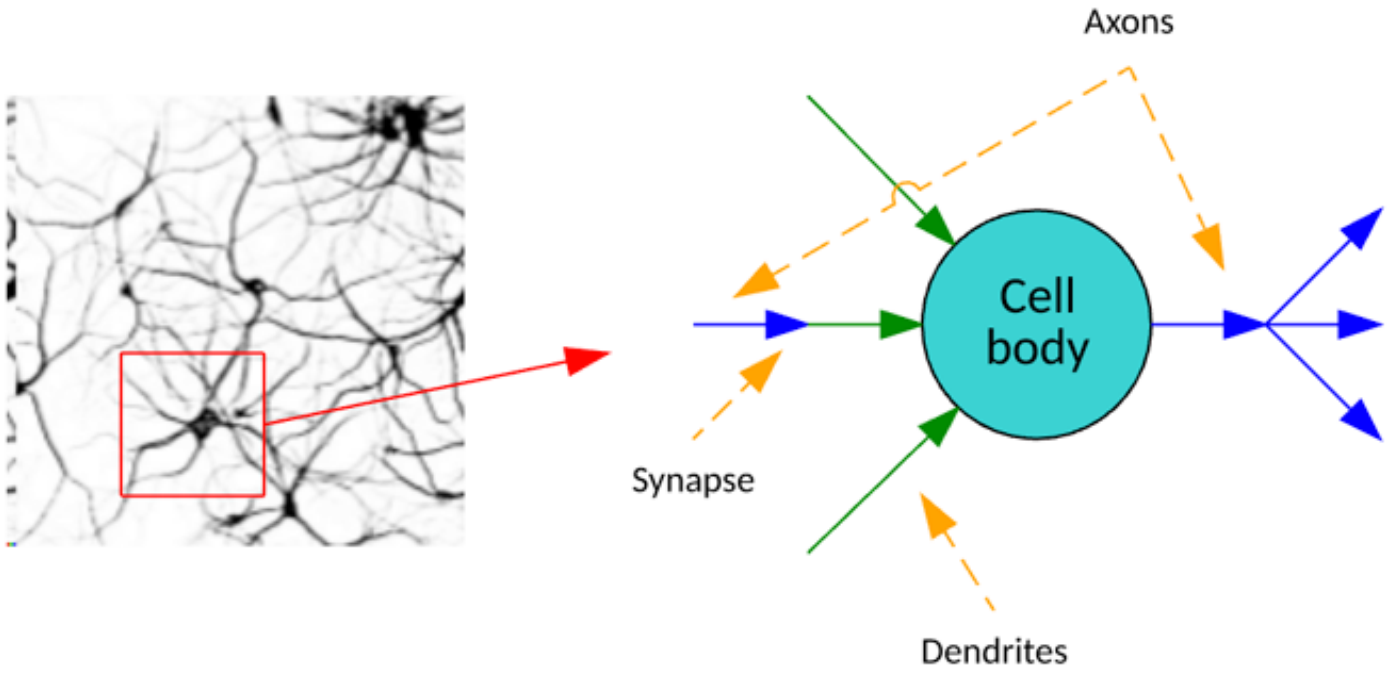
Where to place the content of BIC



Artificial Neural Networks

- What is an Artificial Neural Network?

A biologically inspired computational model that simulates the basic functions of biological neurons

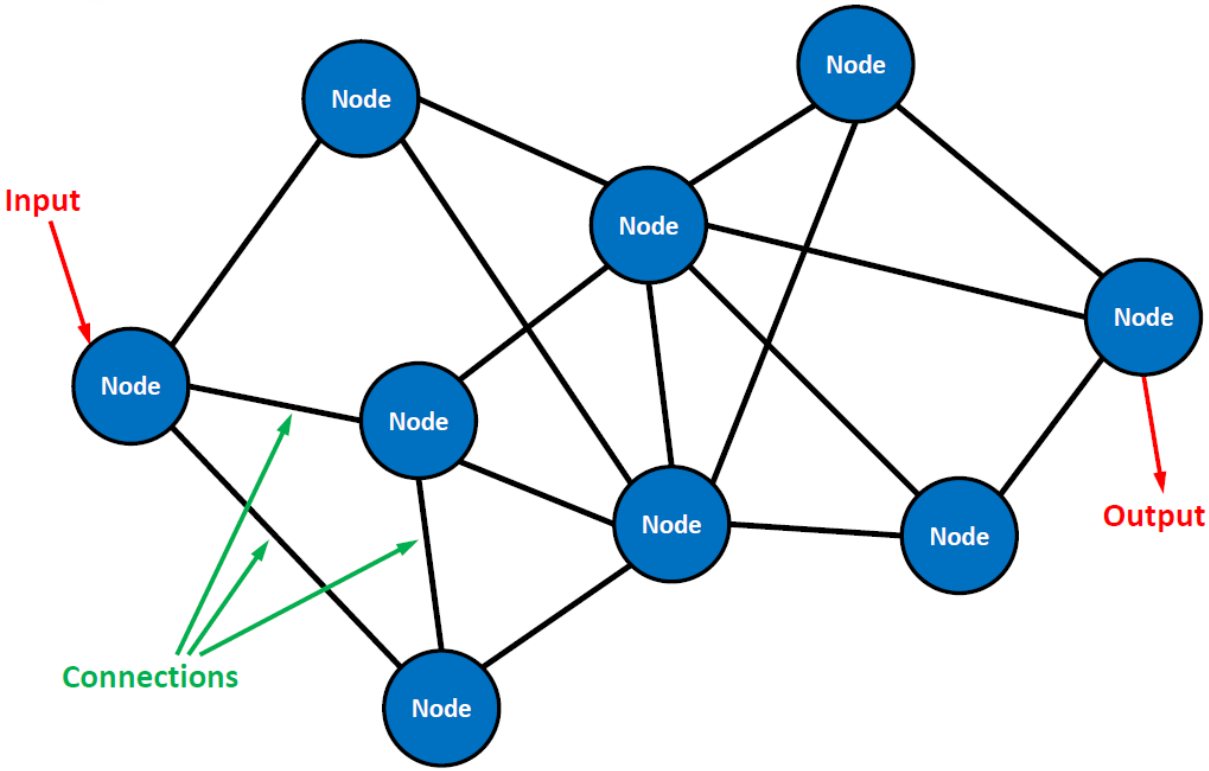


See more about the biological principles of ANN in the **Complementary Material 1**

Artificial Neural Networks

- What is a Neural Network?

ANN is a connectionist model based on the interconnection of similar processing units named **nodes** (**neurons)**.



Universal Regression Systems - Modelling a system with an unknown input-output relationship

Neural Computation

- What is Neural Computation?

  It encompasses distributed (knowledge is shared) and parallel processing (nodes operates independently)

  Learning: a network without knowledge can be trained from the environment through a learning process.

  Pattern recognition & knowledge discovery: associate input patterns to outputs

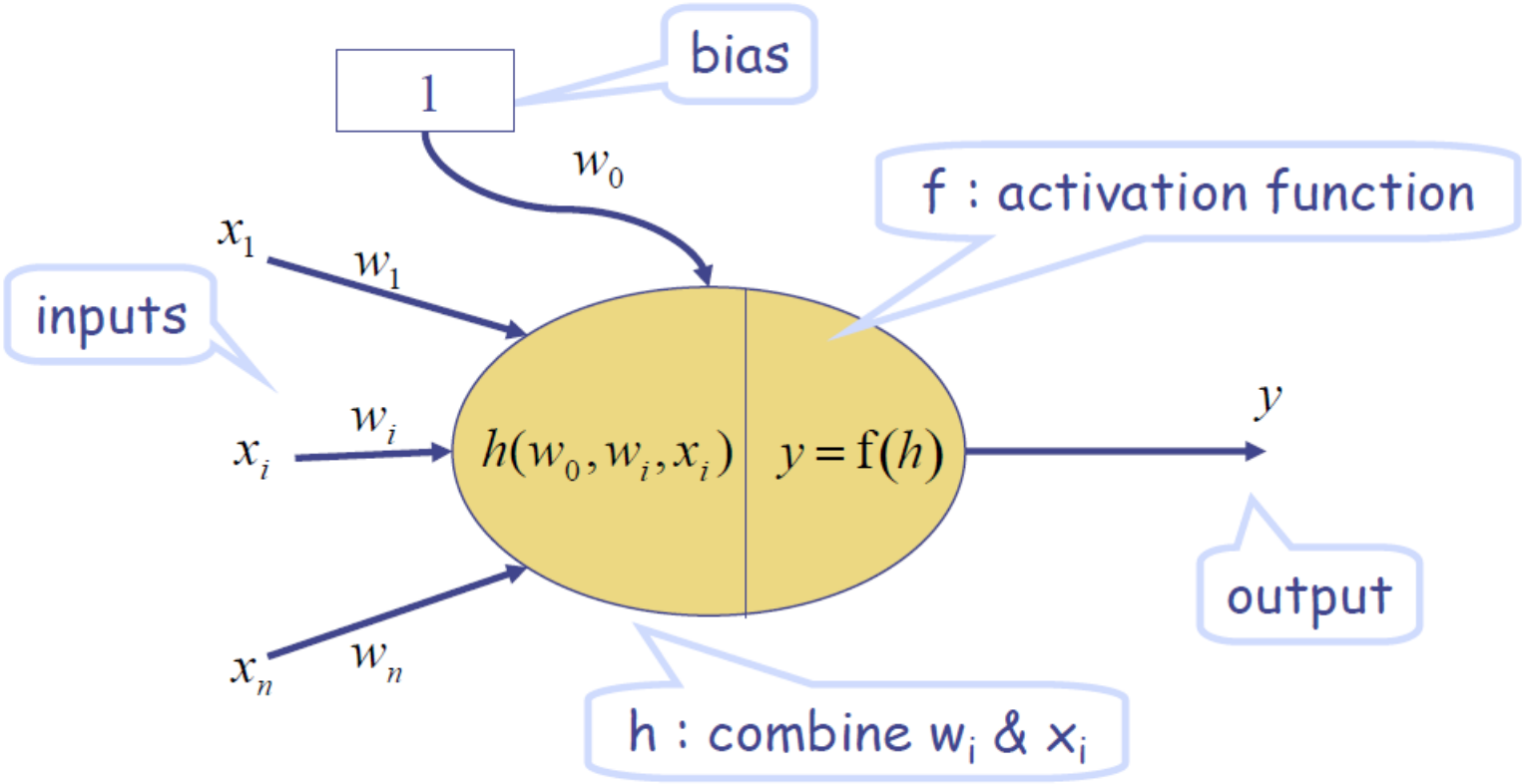
  Generalisation: Produce an output based on its knowledge if a different input is introduced into the network.

  Nonlinearity: Cope with non-linear data

  Fault Tolerance: Good response even if input data is slightly incorrect

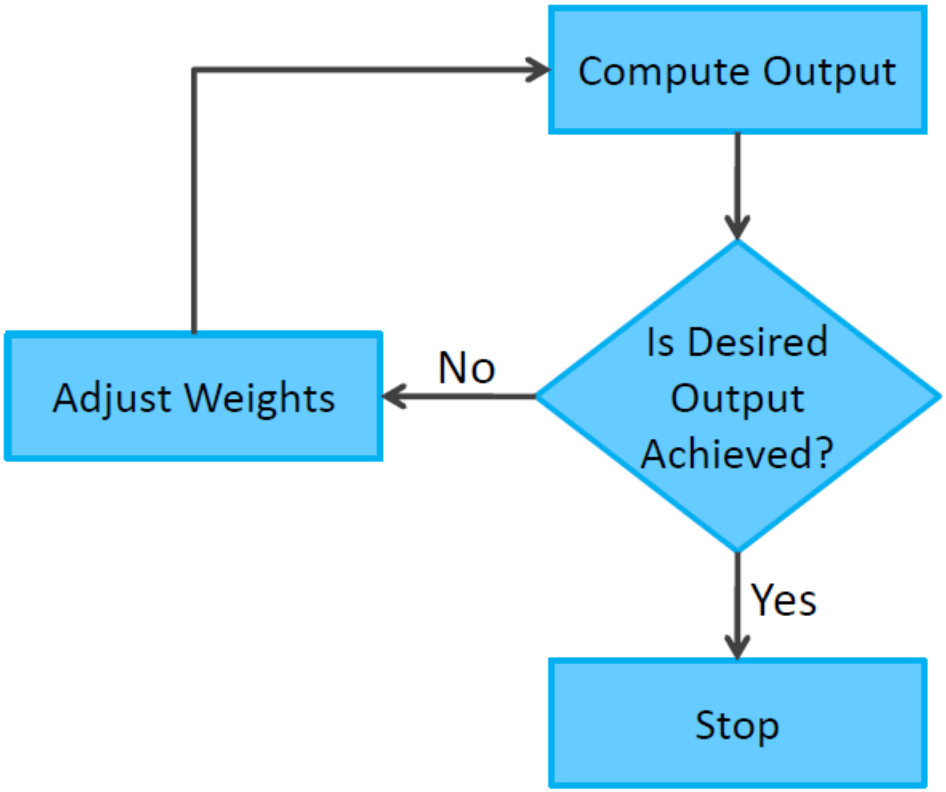
Structure of an Artificial Neuron

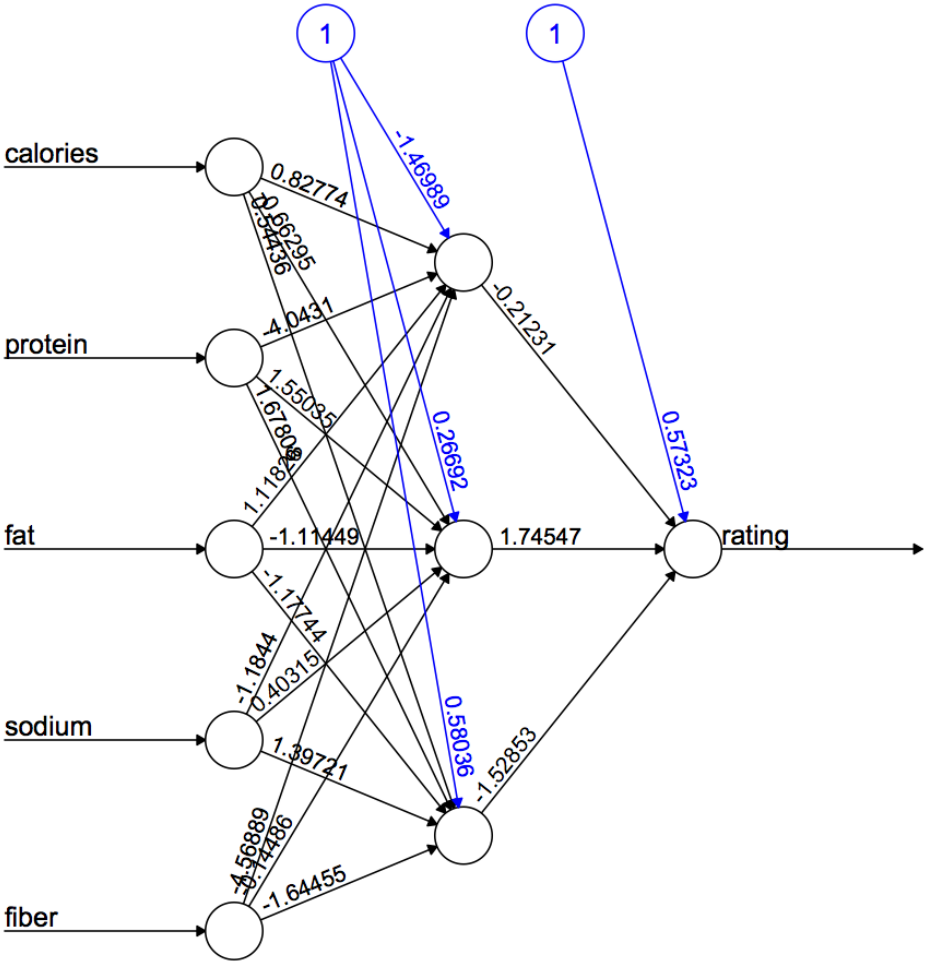
- An artificial neural network consists of :
  - A set of connected nodes (neurons) or units
  - A set of weights associated with these connections
  - A set of thresholds or levels of activation
  - A set of bias



Learning in Artificial Neural Networks

Knowledge: Inter-neuron interconnection strength "synaptic strength"





The learning or training process of neural networks entails the task of finding the most optimal set of weights

Design of an Artificial Neural Network

- The design of a neural network requires :
  - The choice of the number and type of units
  - The determination of the morphological structure (layers)
  - A set of training examples, in terms of inputs and outputs from the network. Sometimes we do not have outputs.
  - The initialisation and training of the weights on the interconnections through the training set
  - The selection of other hyperparameters

Application of Artificial Neural Networks

- **Classification**: Assigning each object to a known specific class
- **Clustering**: Grouping together objects similar to each other
- **Function approximation**: Generating almost the same outputs from input data as a given function
- **Optimisation**: Optimising function values subject to constraints
- **Forecasting**: Predicting future events on the basis of past history
- **Control**: Determining values for input variables to achieve desired values for output variables

Main Types of Artificial Neural Networks

Supervised Learning:

Feed-forward ANN

- Multi-Layer Perceptron
- Deep feed forward Networks
- Convolutional Neural Networks

Recurrent Networks

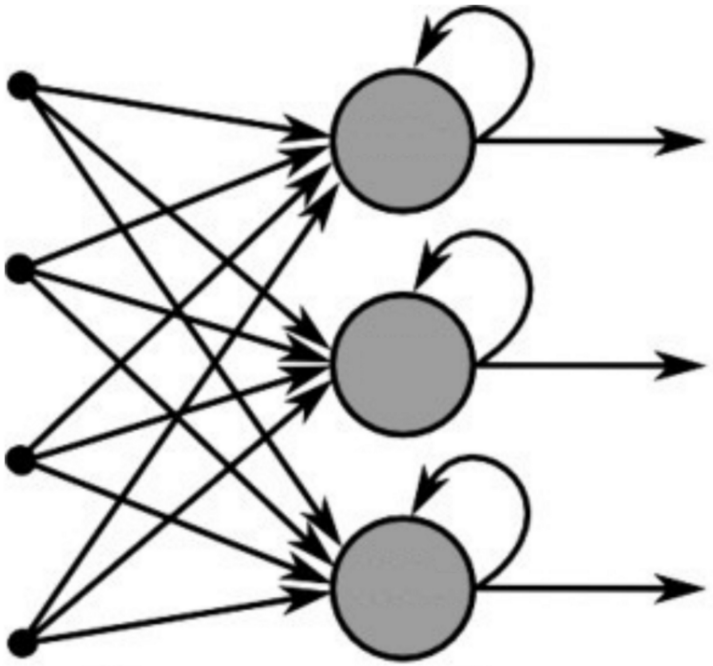
- Hopfield networks
- Gated Recurrent Unit
- Long short-term memory

Unsupervised Learning:

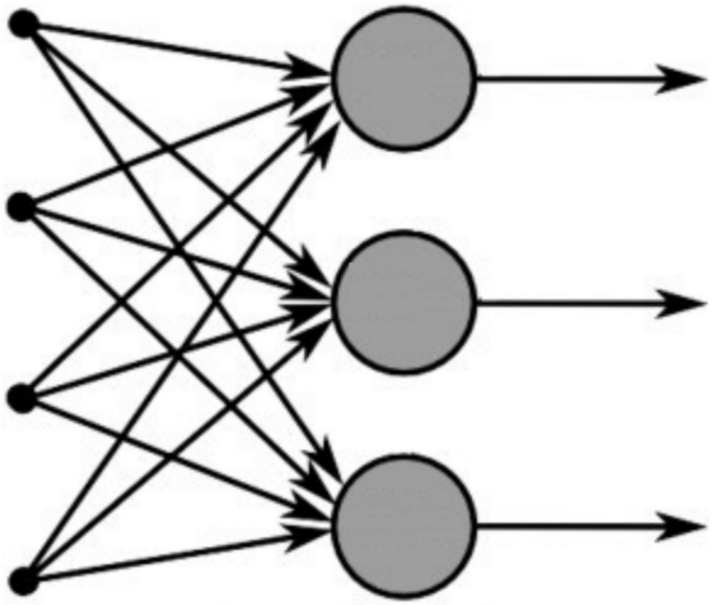
Self-organising ANN

- Belief Networks
- Restricted Boltzmann Machines
- Autoencoders

Feed-forward vs. Recurrent Neural Networks



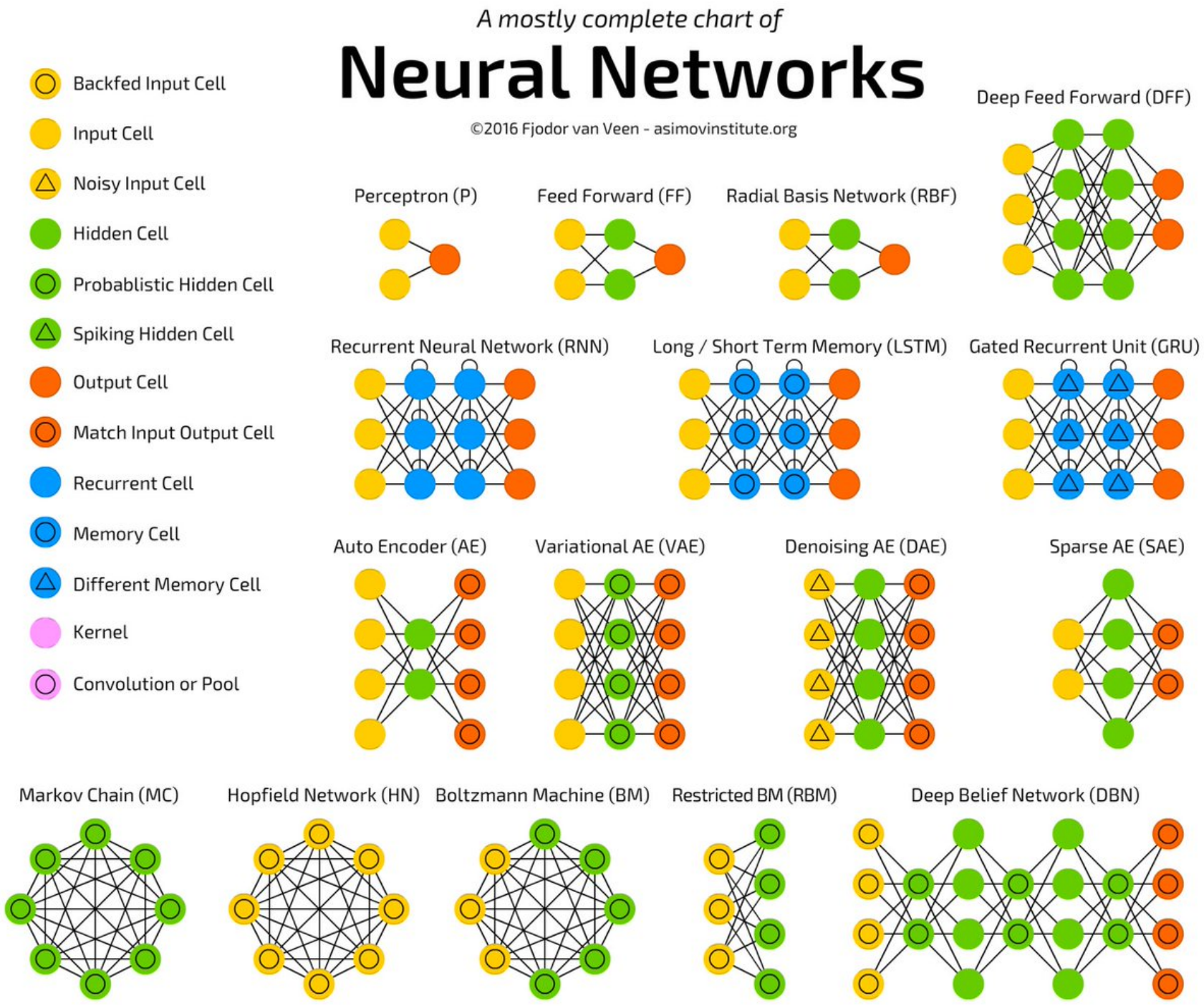
Recurrent Neural Network



Feed-Forward Neural Network

Signals are not restricted in the way they are connected. Loops are allowed

Signals are allowed to travel only from input to output. There is no feedback (loops)


A mostly complete chart of
Neural Networks
©2016 Fjodor van Veen - asimovinstitute.org
Backfed Input Cell
Input Cell
Noisy Input Cell
Hidden Cell
Probablistic Hidden Cell
Spiking Hidden Cell
Output Cell
Match Input Output Cell
Recurrent Cell
Memory Cell
Different Memory Cell
Kernel
Convolution or Pool
Perceptron (P)
Feed Forward (FF)
Radial Basis Network (RBF)
Deep Feed Forward (DFF)
Recurrent Neural Network (RNN)
Long / Short Term Memory (LSTM)
Gated Recurrent Unit (GRU)
Auto Encoder (AE)
Variational AE (VAE)
Denoising AE (DAE)
Sparse AE (SAE)
Markov Chain (MC)
Hopfield Network (HN)
Boltzmann Machine (BM)
Restricted BM (RBM)
Deep Belief Network (DBN)

How can I know more?

I recommend you this site, where you can find tones of information about Neural Networks and Deep Learning:

https://github.com/souravstat/Curated-Resources/blob/master/Great%20Deep%20Learning%20Tutorials.md#books

Credit for this collection:
Guillaume Chevalier