Neural Networks

Lecture 5

Neural Network Architectures (1)

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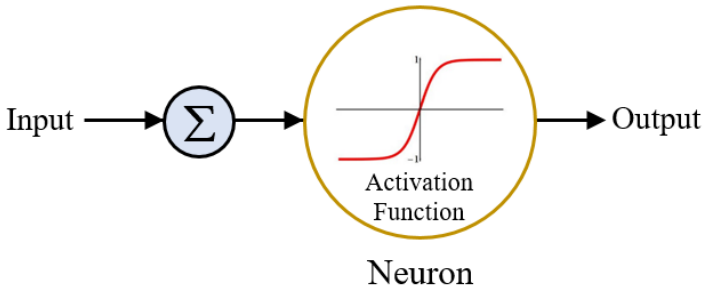
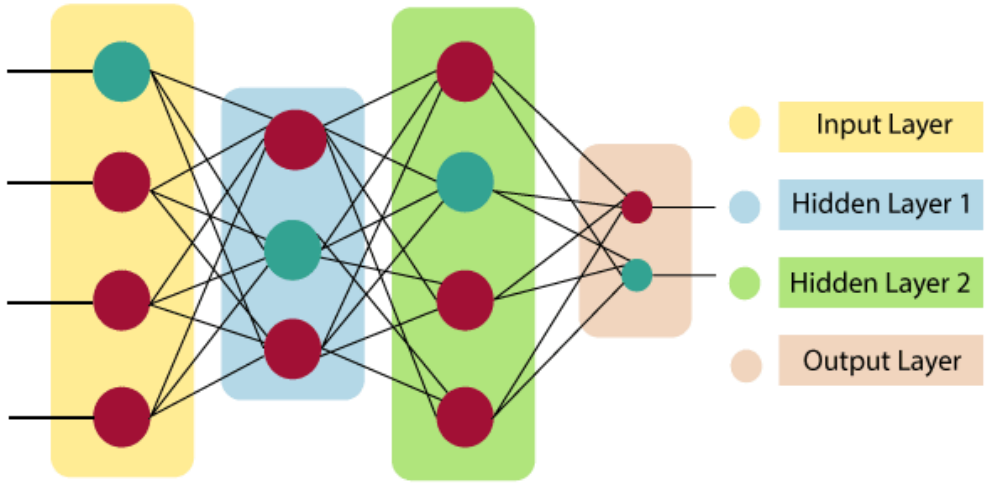


Basic Architecture of an ANN…

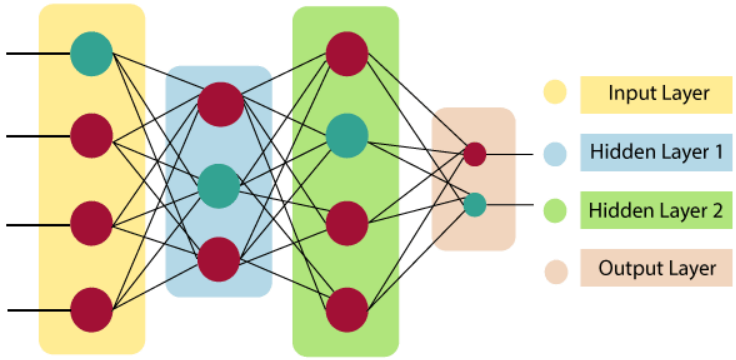
- The **arrangement of neurons into layers** and the connection patterns within and between layers is called **the net architecture**.
- To understand the concept of the architecture of an artificial neural network, we have to understand **what a neural network consists of**. In order to define a neural network that consists of a large number of artificial neurons, which are termed units arranged in a sequence of layers.
- Artificial Neural Network primarily consists of **three layers, input layer, hidden layer and output layer**.



Basic Architecture of an ANN

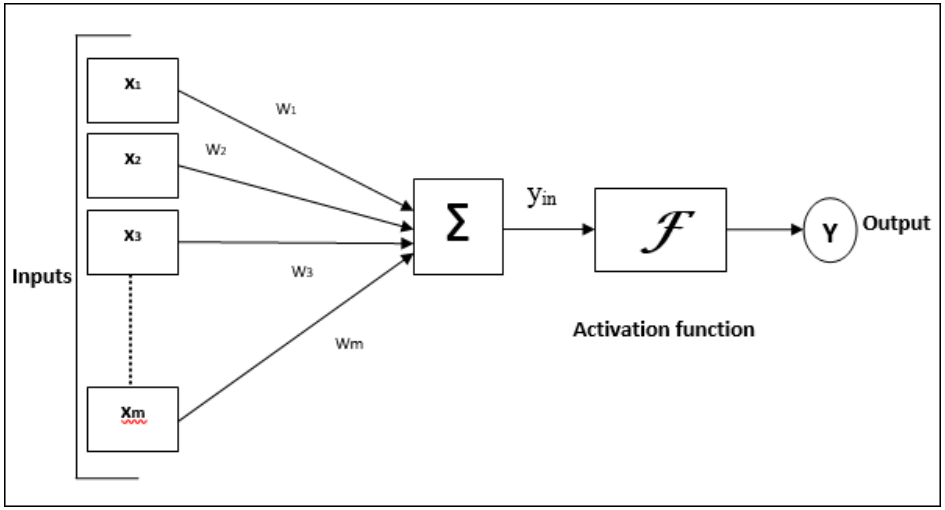
- **Input Layer:** As the name suggests, **it accepts inputs in several different formats** provided by the programmer.
- **Hidden Layer:** The hidden layer presents in-between input and output layers. **It performs all the calculations to find hidden features and patterns**.
- **Output Layer:** The input goes through a series of transformations using the hidden layer, **which finally results in output that is conveyed using this layer**.
- The artificial neural network **takes input and computes the weighted sum of the inputs** and includes a bias. This computation is represented in the form of **a transfer function**.

$$\sum_{i=1}^{n} Wi * Xi + b$$



ANN Model and Net Input…

- The following diagram represents the general model of ANN followed by its processing.



- For the above general model of artificial neural network, the net input can be calculated as follows −

$$y_{in} = x_1 . w_1 + x_2 . w_2 + x_3 . w_3 \ldots x_m . w_m$$

i.e., Net input $y_{in} = \sum_i^m x_i . w_i$

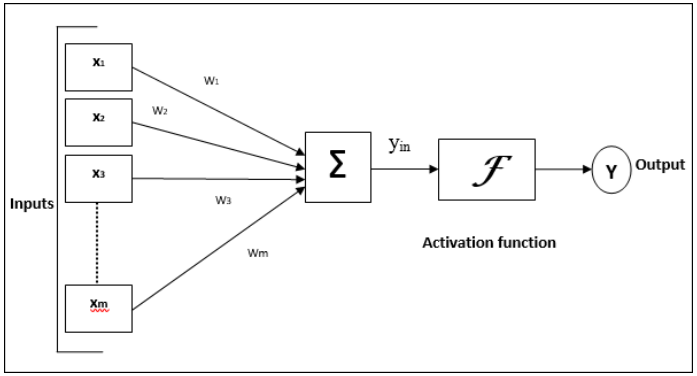
ANN Model and Net Input

- The output can be calculated by **applying the activation function over the net input**.

$$Y = F(y_{in})$$

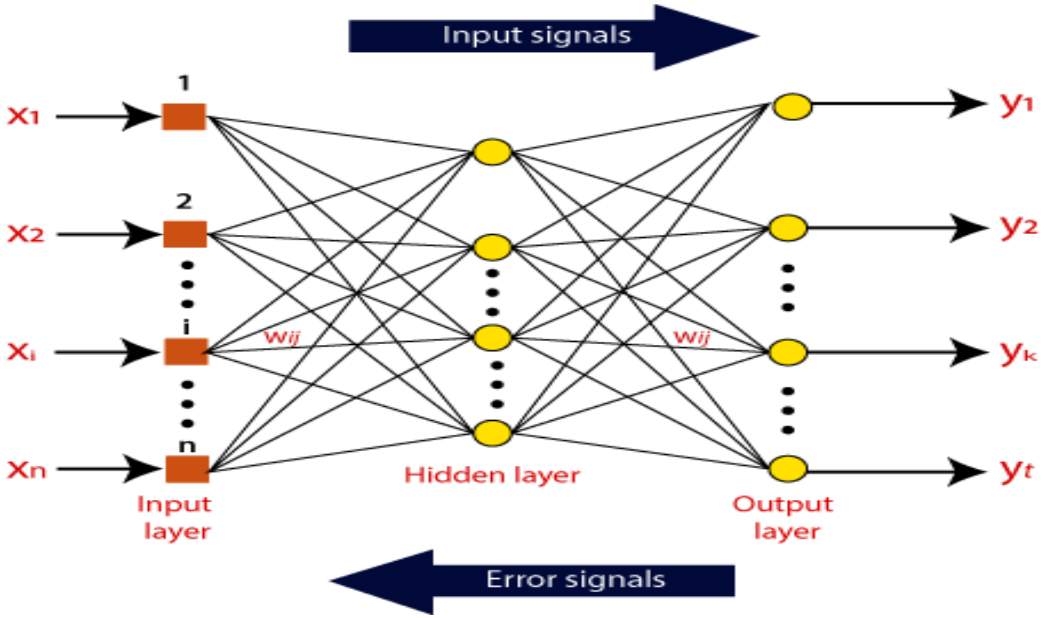
Output = Function (*Net_Input_Calculated*)

- **It determines weighted total is passed as an input to an activation function to produce the output**. Activation functions choose whether a node should fire or not. Only those who are fired make it to the output layer. There are distinctive activation functions available that can be applied upon the sort of task we are performing.



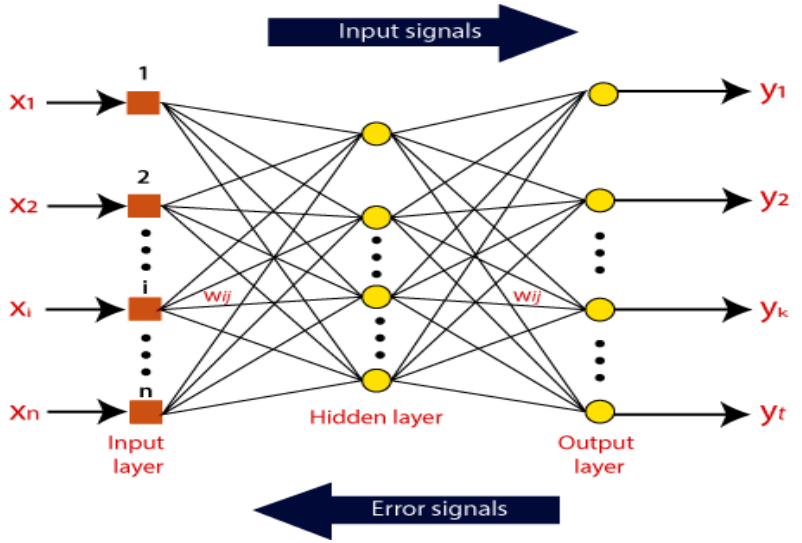
How do ANNs work?...

- Artificial Neural Network can be best represented as a weighted directed graph, where the artificial neurons form the nodes. **The association between the neurons outputs and neuron inputs can be viewed as the directed edges with weights**.
- The Artificial Neural Network receives **the input signal from the external source in the form of a pattern and image in the form of a vector**.



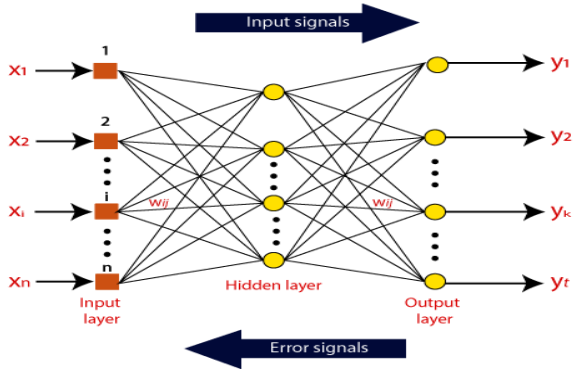
How do ANNs work?...

- These inputs are then mathematically assigned by the notations x(n) for every n number of inputs. **The weighted input is passed to an activation function to produce output, y(n)**.
- Information flows through a neural network in two ways. When it's learning (being trained) or operating normally (after being trained), patterns of information are fed into the network via the input units, which trigger the layers of hidden units, and these in turn arrive at the output units.



How do ANNs work?

- This common design is called a **feedforward network**. Not all units "fire" all the time. **Each unit receives inputs from the units to its left, and the inputs are multiplied by the weights of the connections they travel along**.
- Every unit adds up all the inputs it receives in this way. If the sum is more than a certain **threshold** value, the unit "fires" and triggers the units it's connected to (those on its right).
- For a neural network to learn, there has to be an element of **feedback**. **The feedback in involved to compare the desired outcome with actual output**. It needs to figure out the difference between the two (errors), and minimize the errors by adjusting the weights.



Building Blocks of ANN

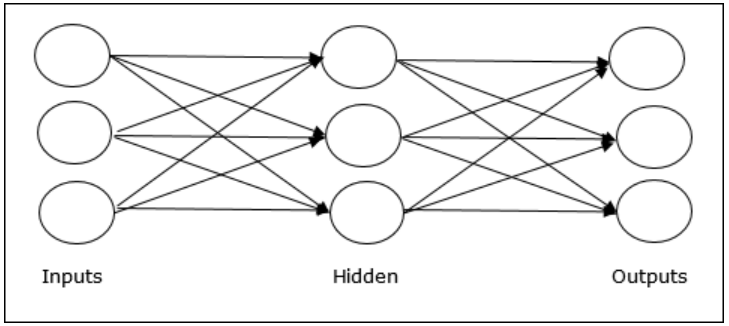
- Neural networks are made of shorter modules or building blocks, same as atoms in matter and logic gates in electronic circuits. Once we know what the blocks are, we can combine them to solve a variety of problems.
- Processing of Artificial neural network depends upon the given three building blocks:
  - Network Topology
  - Adjustments of weights or learning
  - Activation functions

Network Topology…

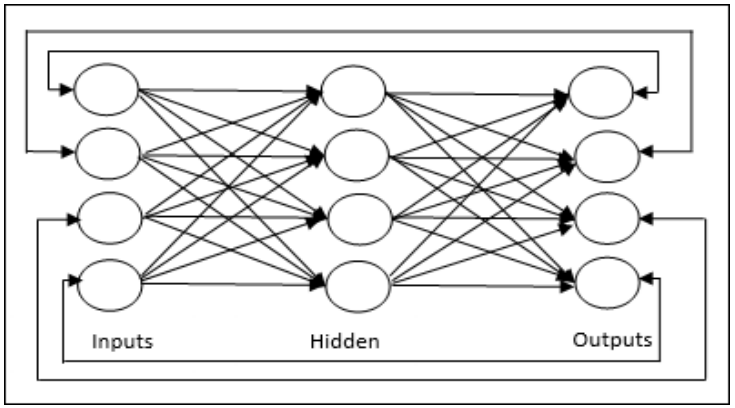
- A network topology is the arrangement of a network along with its nodes and connecting lines. It refers to the way how Neurons are associated, and it is a significant factor in network functioning and learning.
  1. A common topology in unsupervised learning is a direct mapping of inputs to a group of units that represents categories, for example, self-organizing maps.
  2. The most widely recognized topology in supervised learning is completely associated, three-layer, feedforward network (Backpropagation, Radial Basis Function Networks).
- All input values are associated with all neurons in the hidden layer (hidden because they are not noticeable in the input or the output), the output of the hidden neurons are associated to all neurons in the output layer, and the activation functions of the output neurons establish the output of the entire network.

Network Topology…

- According to the topology, ANN can be classified as the following kinds −
  - Feedforward Network
    - Single layer feedforward network
    - Multilayer feedforward network

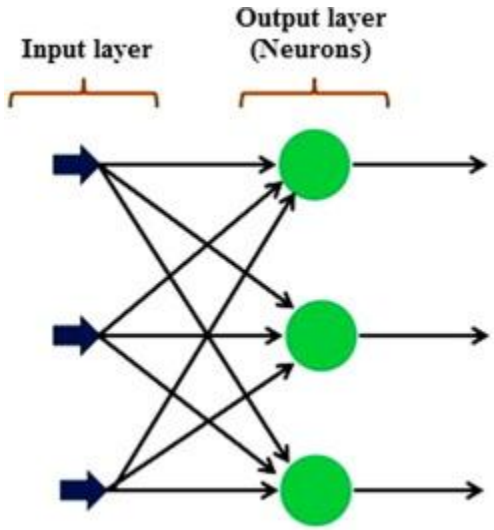


  - Feedback Network
    - Recurrent networks
    - Fully recurrent network
    - Jordan network

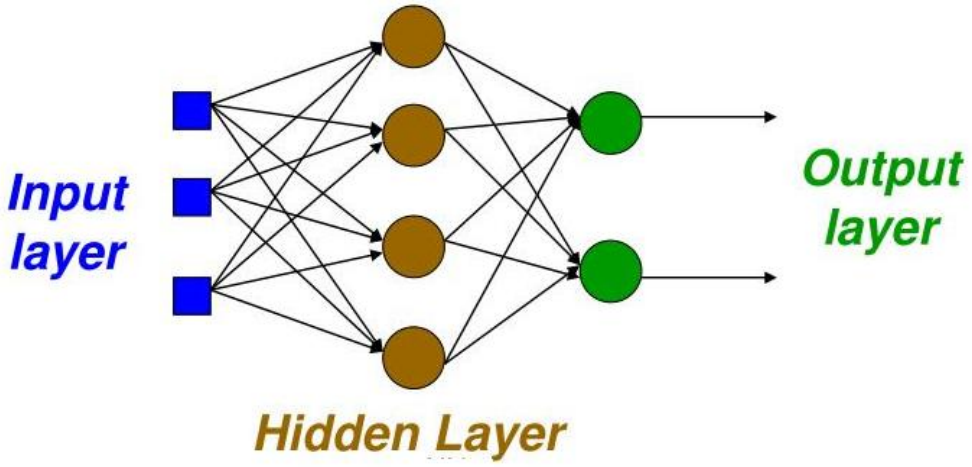


Network Topology…

- Feedforward Network: **Single layer and Multilayer feedforward networks**



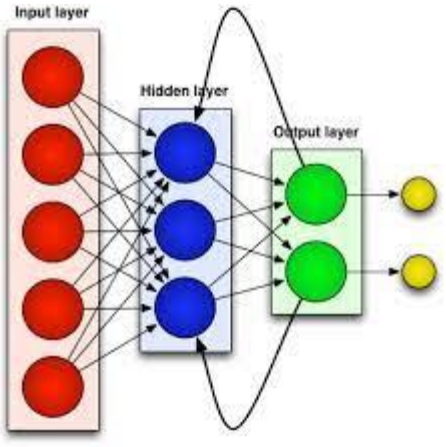
Single layer feedforward networks



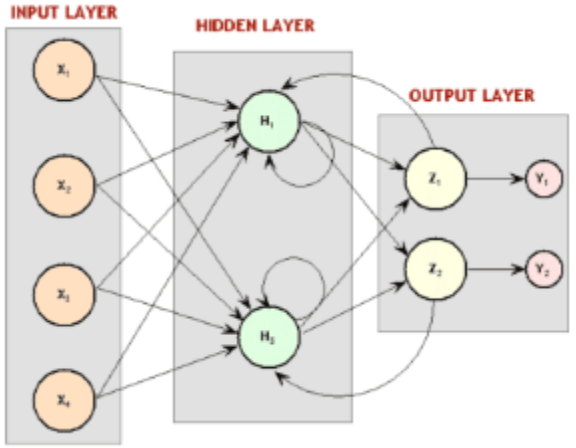
Multilayer feedforward networks

Network Topology

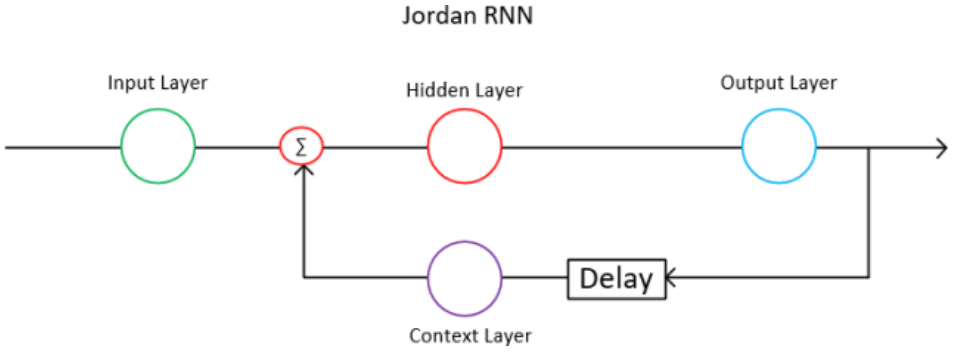
- Feedback Network: **Recurrent, Fully recurrent and Jordan networks**



Recurrent Network



Fully Recurrent Network



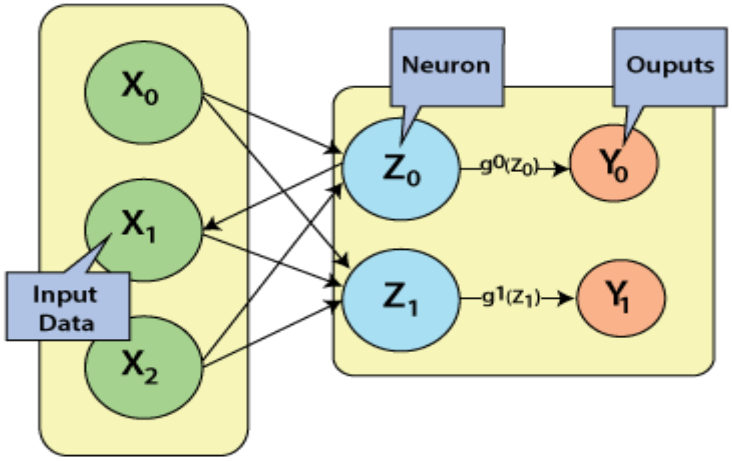
Jordan Network

Feedforward Network…

- The advancement of layered feed-forward networks initiated in the late **1950s**, given by **Rosenblatt's** perceptron and **Widrow's** Adaptive linear Element (ADLINE).
- The perceptron and ADLINE can be defined as a single layer networks and are usually referred to as single-layer perceptron's. Single-layer perceptron's can only solve linearly separable problems.
- The limitations of the single-layer network have prompted the advancement of multi-layer feed-forward networks with at least one hidden layer, called multi-layer perceptron (MLP) networks.
- MLP networks overcome various limitations of single-layer perceptron's and can be prepared to utilize the backpropagation algorithm. In 1974, Werbos created a backpropagation training algorithm

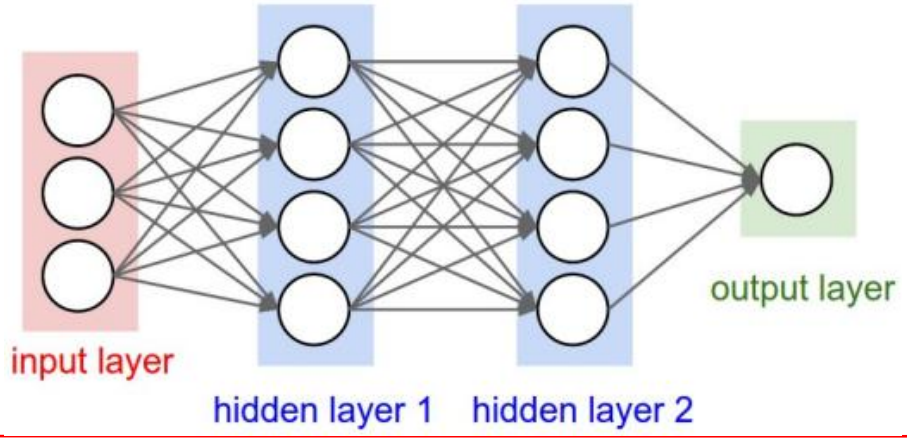
Feedforward Network…

- **Single-layer feedforward network:**
  - Rosenblatt first constructed the single-layer feedforward network in the late 1950s and early 1990s.
  - The concept of feedforward artificial neural network having just one weighted layer.
  - In other words, we can say that the input layer is completely associated with the output layer.



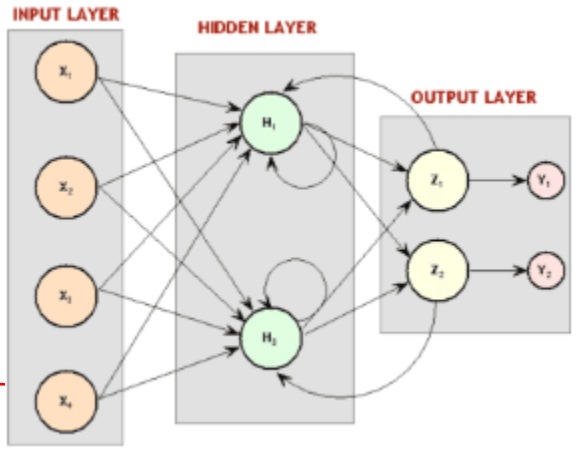
Feedforward Network

- **Multilayer feedforward network:**
  - A multilayer feedforward neural network is a linkage of perceptrons in which information and calculations flow are uni-directional, from the input data to the outputs.
  - The total number of layers in a neural network is the same as the total number of layers of perceptrons. The easiest neural network is one with a single input layer and an output layer of perceptrons.
  - The concept of feedforward artificial neural network having more than one weighted layer. As the system has at least one layer between the input and the output layer, it is called the hidden layer.



Feedback Network…

- A feedback based prediction refers to an approximation of an outcome in an iterative way where each iteration's operation depends on the present outcome. Feedback is a common way of making predictions in different fields, ranging from control hypothesis to psychology.
- Using feedback associations is also additionally exercised by biological organisms, and the brain is proposing a vital role for it in complex cognition.
- In other words, we can say that a feedback network has feedback paths, which implies the signal can flow in both directions using loops. It makes a non-linear dynamic system, which changes continuously until it reaches the equilibrium state.
- It may be divided into the following types:
  - ✓ Recurrent networks
  - ✓ Fully recurrent network
  - ✓ Jordan network



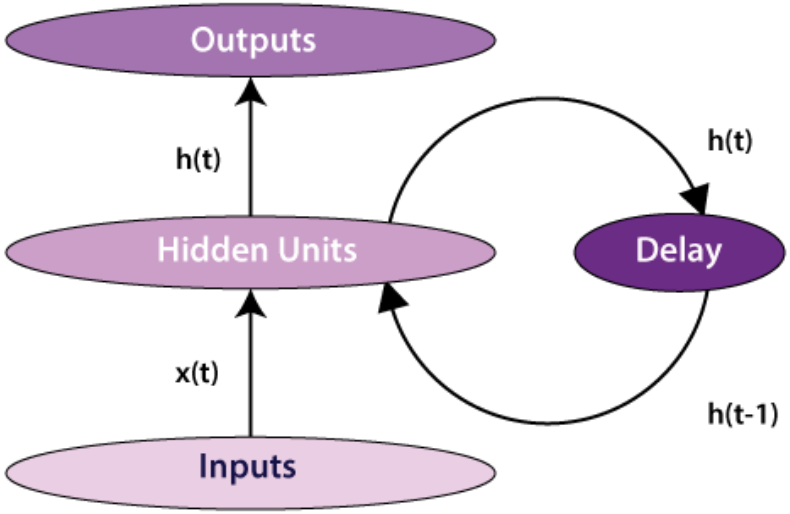
Feedback Network…

- **Recurrent network:**
  - The human brain is a recurrent neural network that refers to a network of neurons with feedback connections. They are feedback networks with closed loops. It can learn numerous behaviors, sequence, processing tasks algorithms, and programs that are not learnable by conventional learning techniques.
  - It explains the rapidly growing interest in artificial recurrent networks for technical applications. For example, general computers that can learn algorithms to map input arrangements to output arrangements, with or without an instructor. They are computationally more dominant and biologically more conceivable than other adaptive methodologies. For example, Hidden Markov models (no continuous internal states), feedforward networks, and supportive vector machines (no internal states).
  - Following are the two types of recurrent networks.
    - Fully recurrent network
    - Jordan network

Feedback Network…

- **Fully recurrent network:**
  - The most straightforward form of a fully recurrent neural network is a Multi-Layer Perceptron (MLP) with the previous set of hidden unit activations, feeding back along with the inputs. In other words, it is the easiest neural network design because all nodes are connected to all other nodes and each node works as both input and output.

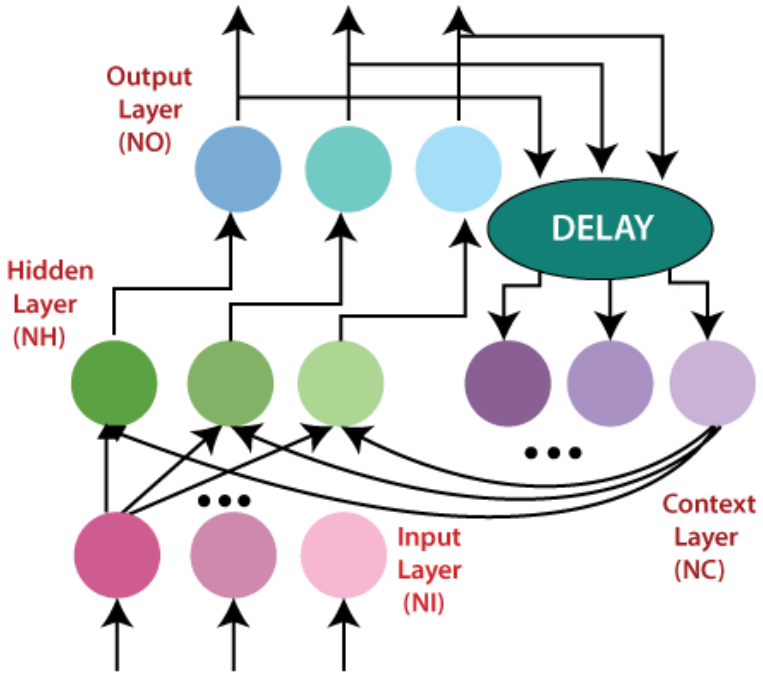
- Note that the time '**t**' has to be discretized, with the activations updated at each time interval. The time scale may compare to the activity of real neurons, or for artificial systems whenever step size fitting for the given problem can be used. A delay unit should be introduced to hold activations until they are prepared at the next time interval.



Feedback Network

- **Jordan network:**
  - The Jordan network refers to a simple neural structure in which only one value of the process input signal (from the previous sampling) and only one value of the delayed output signal of the model (from the previous sampling) are utilized as the inputs of the network. It is a closed loop network in which the output will go to the input again as feedback as shown in the following diagram.

- ✓ In order to get a computationally basic MPC (Model Predictive Control) algorithm, the nonlinear Jordan neural model is repeatedly linearized on line around an operating point, which prompts a quadratic optimization issue.
- ✓ Adequacy of the described MPC algorithm is compared with that of the nonlinear MPC scheme with on-line nonlinear optimization performed at each sampling instant.



NEURAL NETWORK ARCHITECTURES

To be continued…