Neural Networks
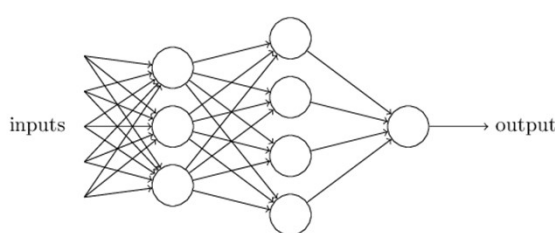

Network Topology *(architecture)*

- By **network topology**, we mean the patterns and structures in the collection of inter-connected **nodes**.
- An example network is shown here.

Contd...

- The topology **determines** the complexity of tasks that can be learned by the network.
- A variety of neural networks **can be created** depending on how the **nodes** are connected.
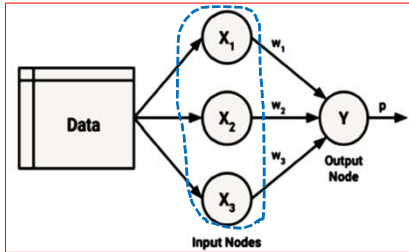

Contd...

- **Topologies can be differentiated by three key characteristics:**
  a) Number of layers.
  b) Whether information in the network is allowed to travel backward *(Direction of information travel).*
  c) The number of nodes within each layer of the network.

a) Number of layers

- Usually the input nodes and the output nodes of an ANN **are arranged in groups** known as **layers**.
- A single – layer neural network is shown below.

Contd…

- Single-layer networks **can be used** for **basic pattern classification**, particularly for patterns that are linearly separable…but…
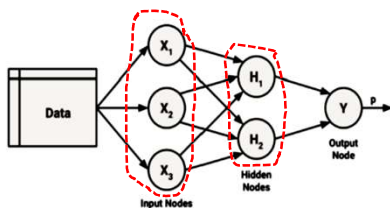 - more sophisticated networks (i.e., **multi-layered networks**) are required for majority of the learning tasks.

Contd…

- A multi-layered neural network is shown below.

- Such a multi-layered neural network **adds** <u>**one or more**</u> **hidden layers**.
- The hidden layers **process** the **signals from the input nodes prior to it (= *the signal*)** reaching the output node.

b) Direction of information travel

- There are two types of neural networks.
  1. **Feedforward Networks**
  2. **Feedback Networks**

b) Direction of information travel

- There are two types of neural networks.
    1. Feedforward Networks
    2. Feedback Networks
- We noted that, arrowheads were used to indicate signals travelling **in one direction only**, i.e., only in **forward direction**.
- ANNs that feed the input signals **continuously in one direction** from connection to connection **until** **it reaches the output layer** are called **feedforward networks**.

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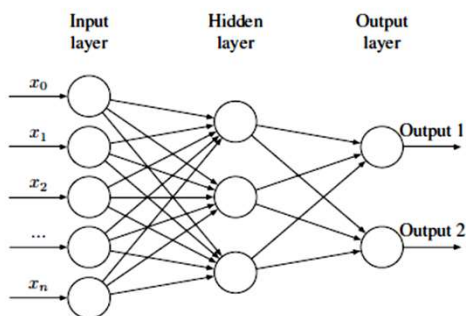GOPEEKRISHNAN R

Contd…

1. **Feedforward Networks**:

- These types of networks
    - **have restriction on information flow**
    - **have certain amount of flexibility**.
- For instance…
    - number of levels can be varied… (i.e., can be increased or decreased)
    - number of nodes at each level can be varied…
    - multiple outcomes can be modeled simultaneously…
    - multiple hidden layers can be applied…
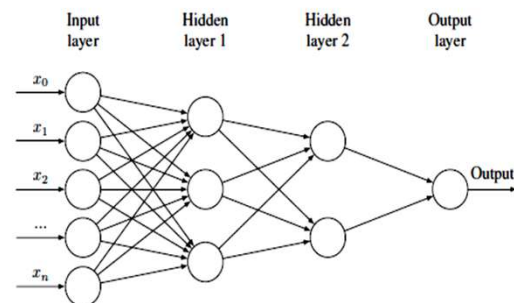
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Contd…

A Neural Network with *multiple* *outputs*

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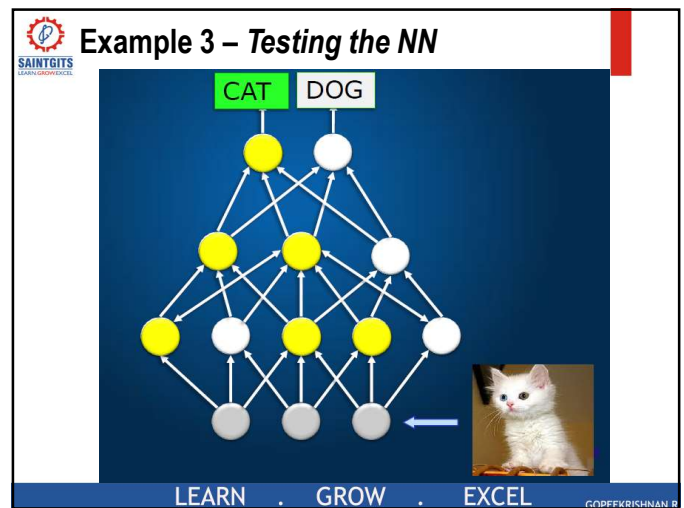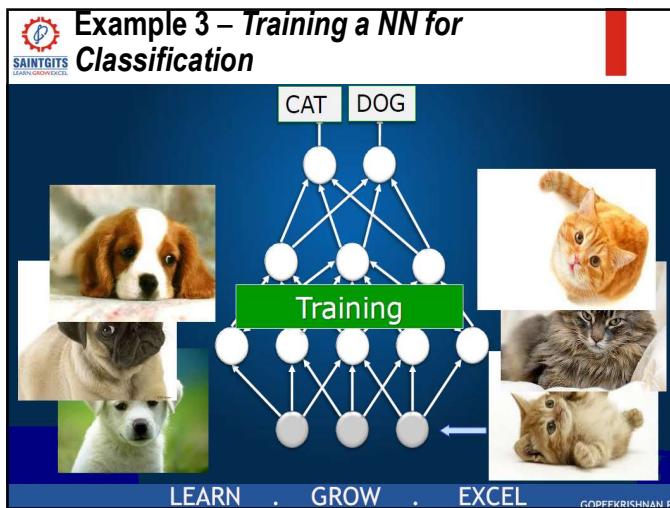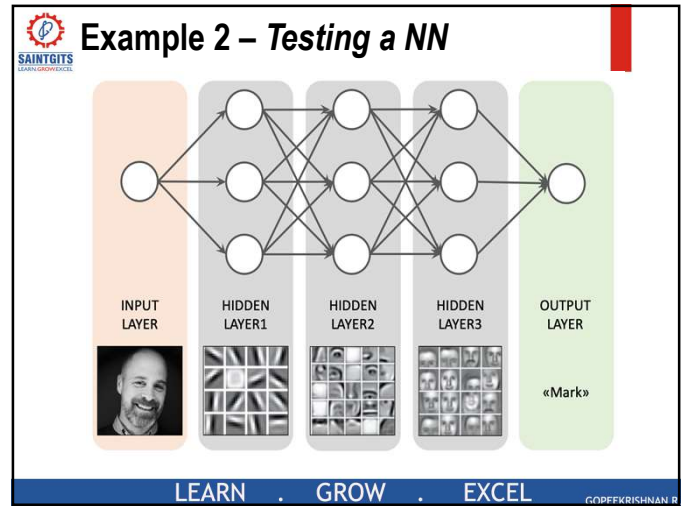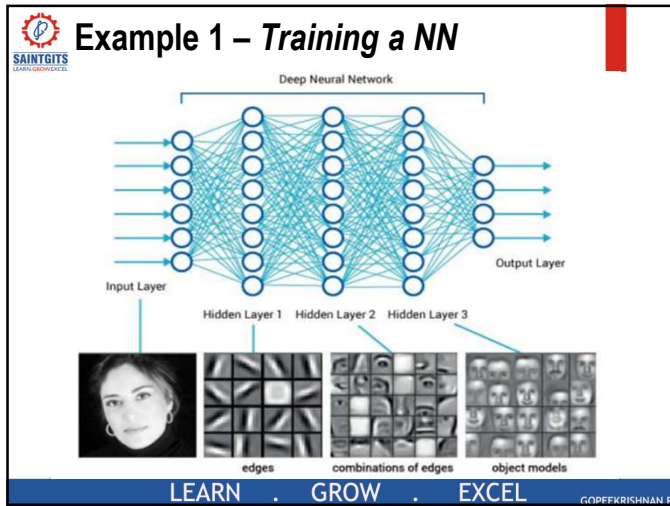## Contd…

A Neural Network with *multiple* *hidden layers*

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Example 1 – *Training a NN*

Example 2 – *Testing a NN*

Example 3 – *Training a NN for Classification*
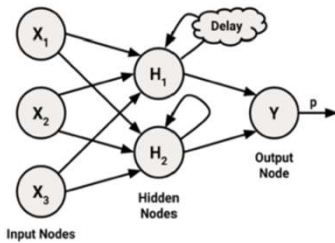

Example 3 – *Testing the NN*

Contd...

2. Feedback Networks:

- Here, signals are allowed to travel in both directions using loops.
- Such networks are also called **recurrent networks**.
- Loops are implemented using short-term memory called the **delay**.

Contd...

- The **delay**…
  - ✓ **increases** the power of feedback networks immensely.
  - ✓ has the capability to **understand the sequences of events over a period of time**.
- Therefore, **suitable** for applications like
  - Stock Market Prediction
  - Weather Forecasting
  - Speech Comprehension

Contd...

- Feedforward Networks are extensively used in most real-world applications.
- In spite of their potential, feedback networks are still largely theoretical and are rarely used in practice.

Contd...

- **De facto Standard for ANN Topology:**
- It is the **Multi-layered Feedforward Network**.
- That is, such a network **must have**
  - *Multiple layers* (input layer, hidden layers and output layer)
  - Direction of information travel in the *forward direction only*.
- Such a network **is also called** Multi-layer perceptron (MLP).
- MLP is also called **Deep Feedforward Neural Network** (also known as **Deep Neural Network**).

c) Number of nodes in each layer

- We need to decide about
    1. Number of nodes to be present in the input layer
    2. Number of nodes to be present in the output layer
    3. Number of nodes to be present in each hidden layer.

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Contd...

- **Number of input nodes is pre-determined** by the number of features in the input data.
- **Number of output nodes is pre-determined** by the number of class levels in the outcome.

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Contd...

- But, the **number of nodes in the hidden layers is left to the user** to decide prior to training the model.
  - There is no reliable rule to determine the number of hidden nodes.
  - Appropriate number of hidden nodes depend on
    - *the number of input nodes*
    - *the amount of training data*
    - *the amount of noisy data*
    - *the complexity of the learning task etc.*

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Contd...

- **Which one will be best?**

GREATER NUMBER OF NODES?
OR
LESSER NUMBER OF NODES?

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Contd...

- If there are a greater number of neurons, we have to consider the following points.

PLUSES	MINUSES
• *It generates a model that closely mirrors the training data.*	• *It runs the risk of overfitting.*
	• *It may generalize poorly to future data.*
	• *Large neural networks can be computationally expensive.*
	• *Large neural networks can be slow to train.*

Contd...

- The **best practice is to use lesser number of nodes**.
- This will result in a neural network that offers a tremendous amount of learning ability.

References

1. Machine Learning with R, Second Edition, Brett Lantz, PACKT Publishing.