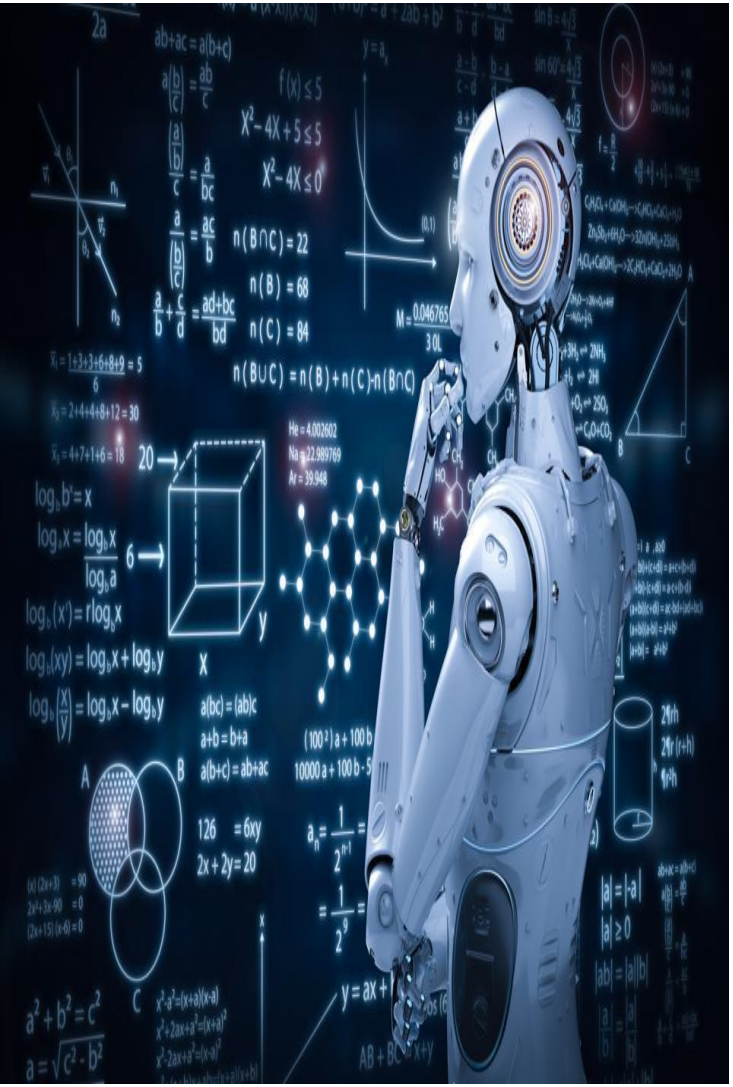


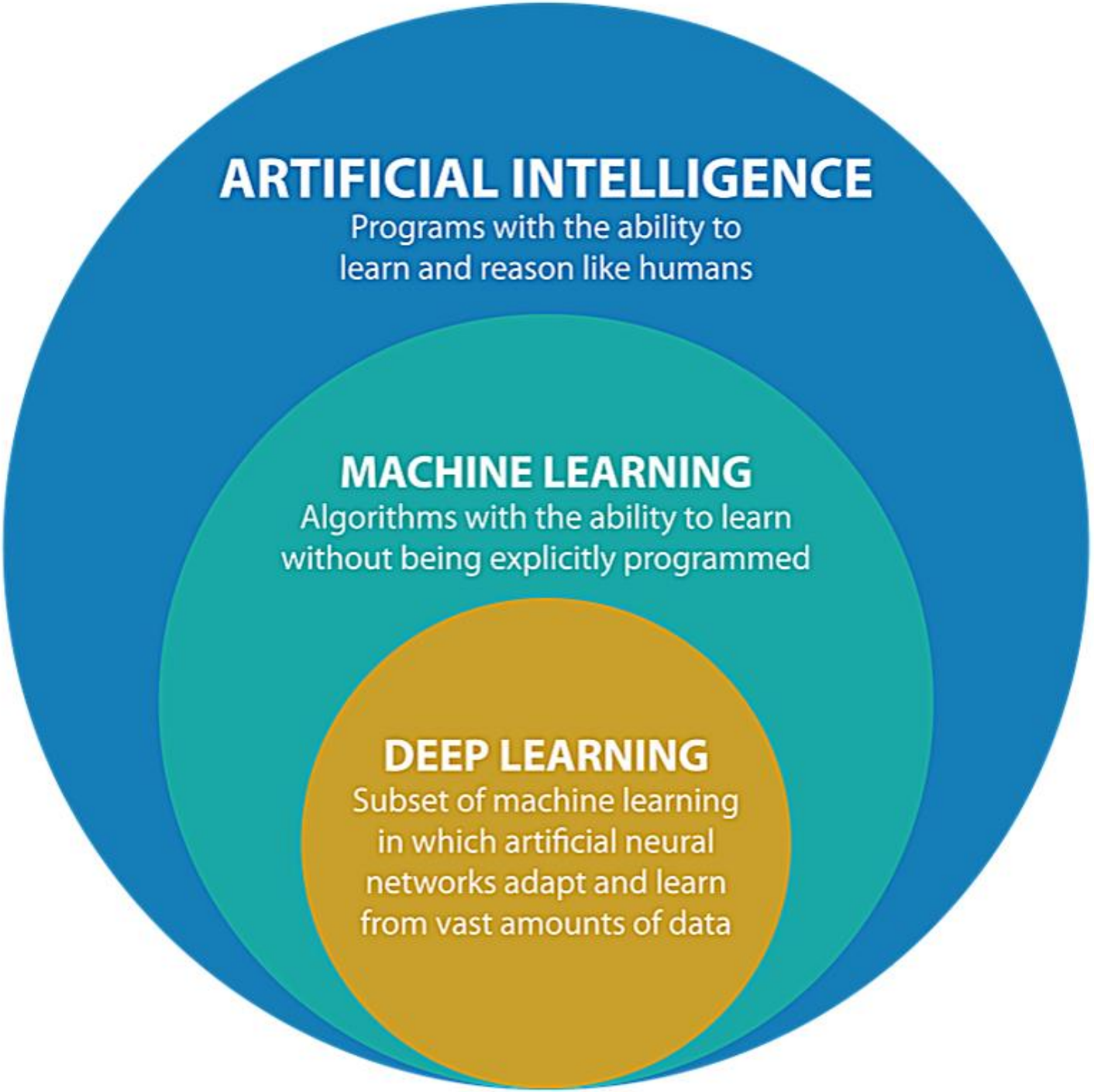
Practical Machine Learning

Day 19: Mar22 DBDA

Kiran Waghmare

Agenda

- Artificial Neural Network


ARTIFICIAL INTELLIGENCE
Programs with the ability to
learn and reason like humans
MACHINE LEARNING
Algorithms with the ability to learn
without being explicitly programmed
DEEP LEARNING
Subset of machine learning
in which artificial neural
networks adapt and learn
from vast amounts of data

Why is Deep Learning Important?

- Causing a revolution in Artificial Intelligence
- Electrifying the computing industry
- Transforming corporate America
- Why? – because over the last five years we have experienced quantum leaps in the quality of many everyday technologies

Fortune, 2016

Why is Deep Learning Important?

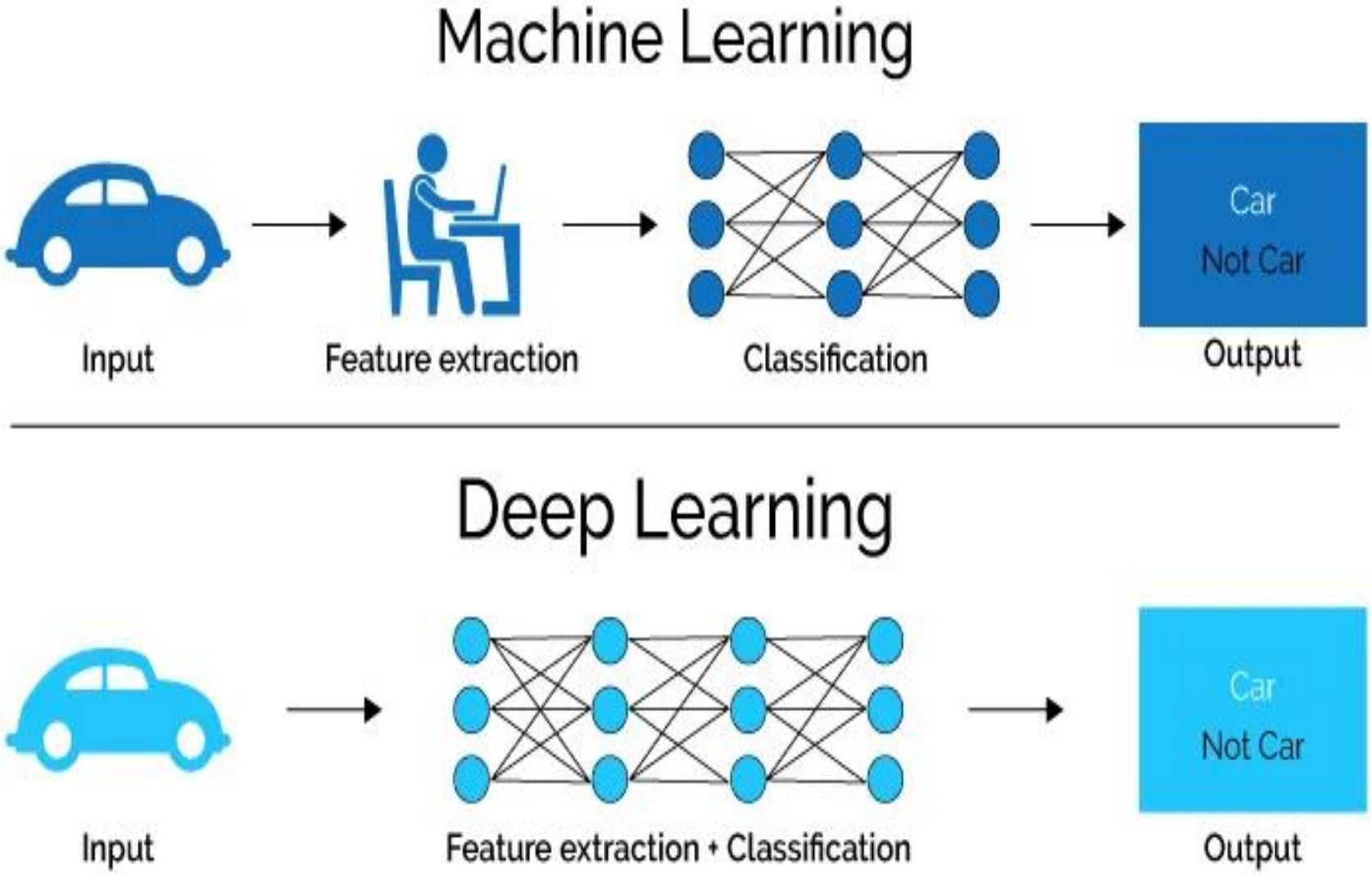
- Major advances in Image Recognition
  - Search and automatically organize collections of photos
    - Apple, Amazon, Microsoft, Facebook
- Speech Technologies work much better
  - Speech recognition: Apple's Siri, Amazon's Alexa, Microsoft's Cortana, Chinese Baidu speech interfaces
  - Translation of spoken sentences: Google Translate
- Deep learning also improving medical applications, robotics, autonomous drones, self-driving cars, etc.

Frank Rosenblatt

Major Types of Deep Learning Systems

- Convolutional Neural Networks for matrix data
  - a type of feed-forward artificial neural network in which the connectivity pattern between its neurons is inspired by the organization of the animal visual cortex
  - often referred to as multilayer perceptrons
- Recurrent Neural Networks for sequential data
  - a class of artificial neural network where connections between units form a directed cycle (feedback)

Frank Rosenblatt


Machine Learning
Input
Feature extraction
Classification
Car
Not Car
Output
Deep Learning
Input
Feature extraction + Classification
Car
Not Car
Output

Deep Neural Network (Pretraining)

SVM

Multi-layered Perceptron (Backpropagation)

XOR Problem

ADALINE

Perceptron

Electronic Brain

Golden Age

Dark Age ("AI Winter")

1943 1957 1960 1969 1986 1995 2006

1940 1950 1960 1970 1980 1990 2000 2010

S. McCulloch - W. Pitts

F. Rosenblatt

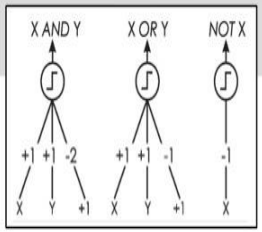
B. Widrow - M. Hoff

M. Minsky - S. Papert

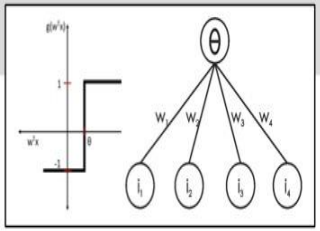
D. Rumelhart - G. Hinton - R. Wiliams

V. Vapnik - C. Cortes

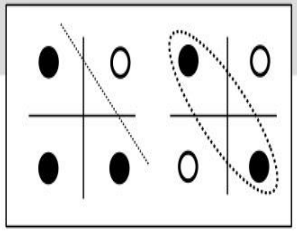
G. Hinton - S. Ruslan



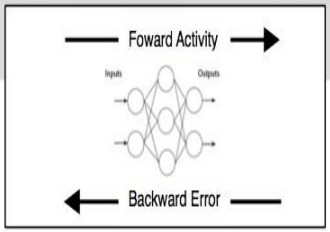
- Adjustable Weights
- Weights are not Learned



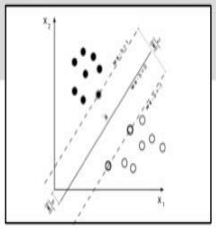
- Learnable Weights and Threshold



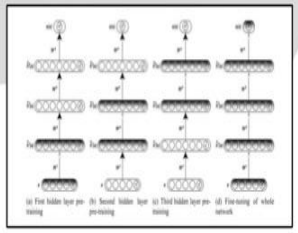
- XOR Problem



- Solution to nonlinearly separable problems
- Big computation, local optima and overfitting

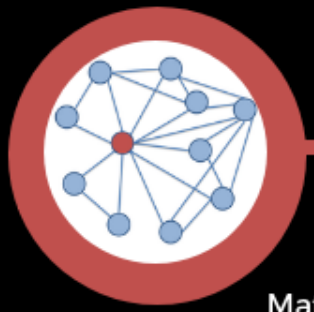


- Limitations of learning prior knowledge
- Kernel function: Human Intervention



- Hierarchical feature Learning

QUANTINSTI®
GO ALGO



1943 — First Mathematical Model of Neural Network

1957 — Pattern recognition using two-layer neural network.

1965 — First working Neural Networks Model

1980 — 'Neocognitron', an Artificial Neural Network developed

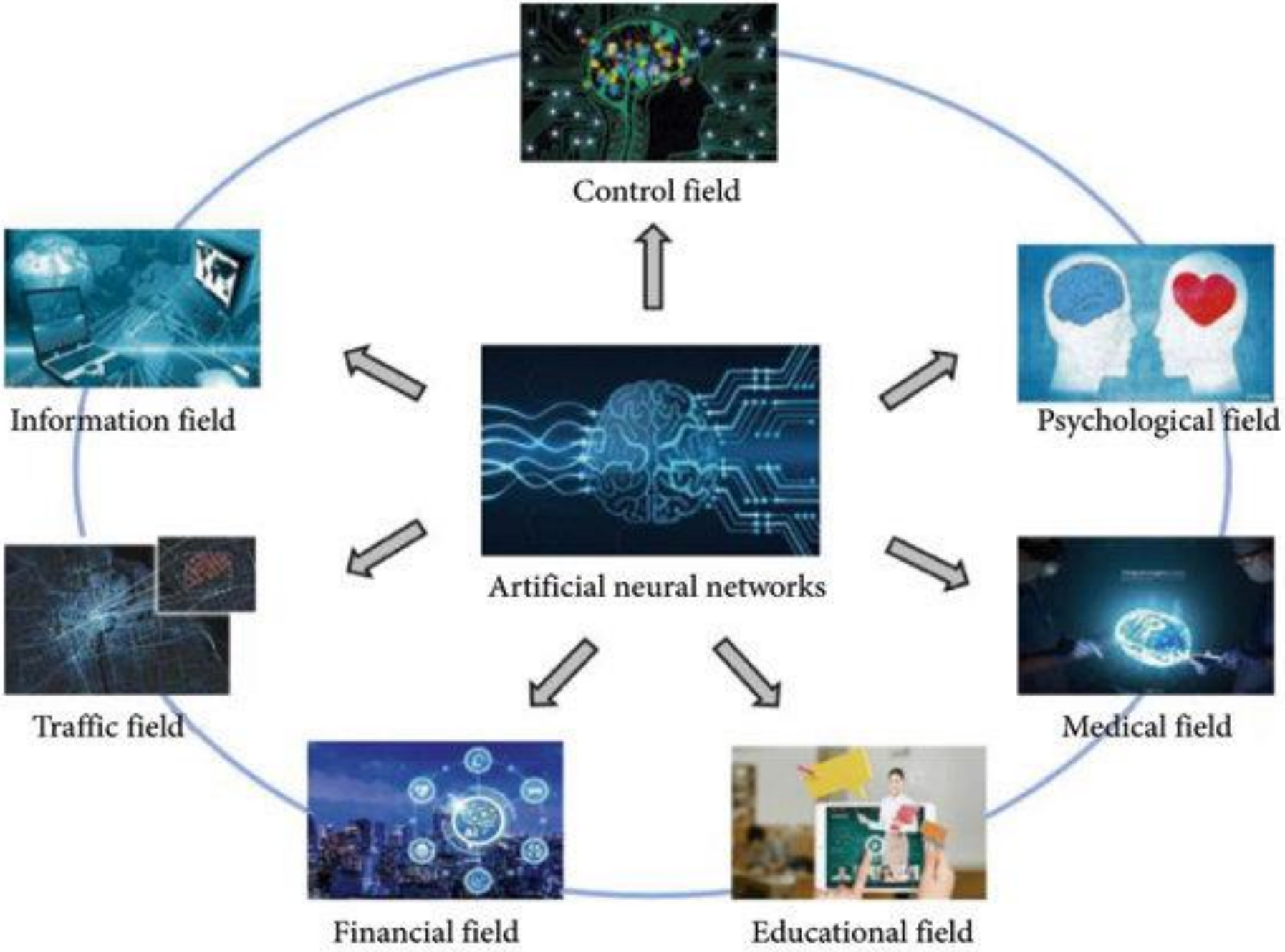
1985 — NETtalk, a program which learnt how to pronounce English words

1989 — A system which could read handwritten digits developed.

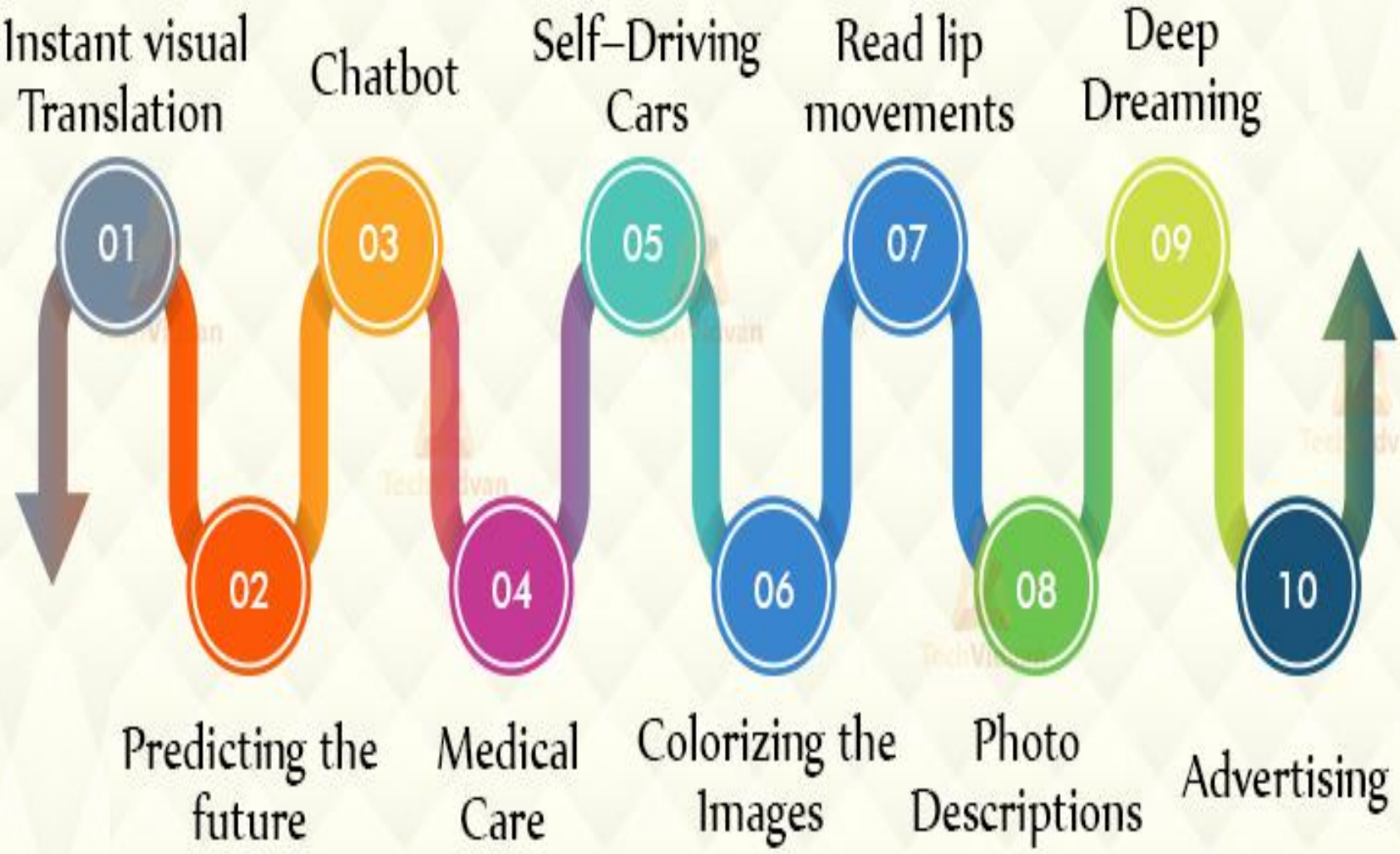
2009 — Launch of ImageNet, a database of labelled data

2012 — 'The Cat Experiment' conducted by Google Brain

2014 — Facebook developed, DeepFace, to identify faces in images


Control field
Information field
Psychological field
Artificial neural networks
Traffic field
Medical field
Financial field
Educational field

Python Deep Learning Applications



Aerospace, Defense and Communications

Communications devices, security

Multi-standard communications receivers, drone recognition

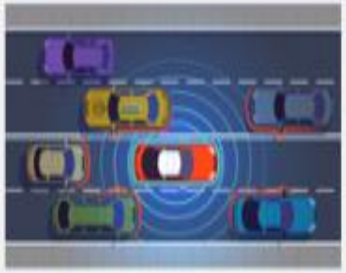
Consumer Electronics and Digital Health

Voice assistants

Digital health

Automotive

Voice control enabled Infotainment



Sensor processing, automated driving

Industrial Automation

Condition monitoring

Predictive maintenance

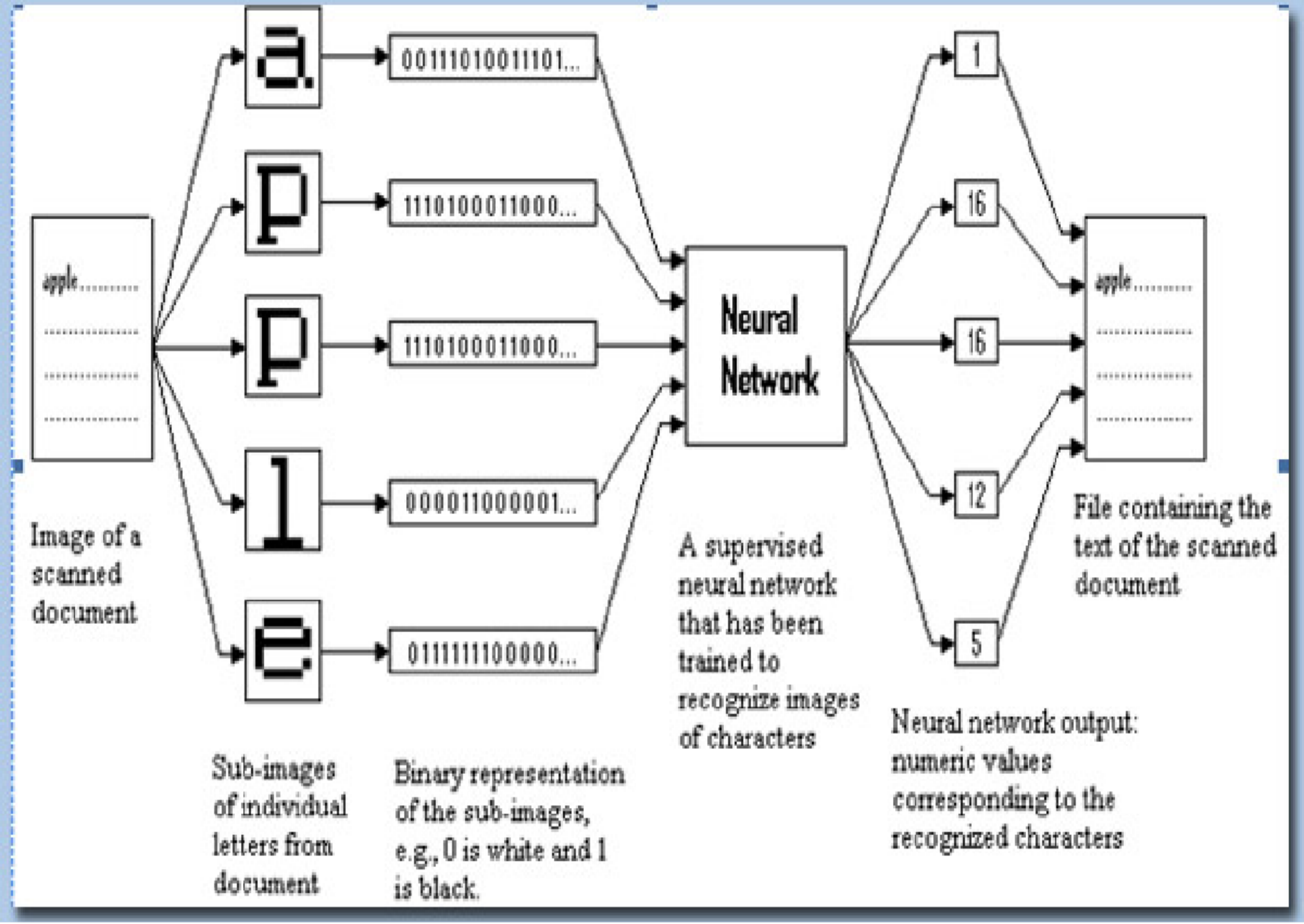
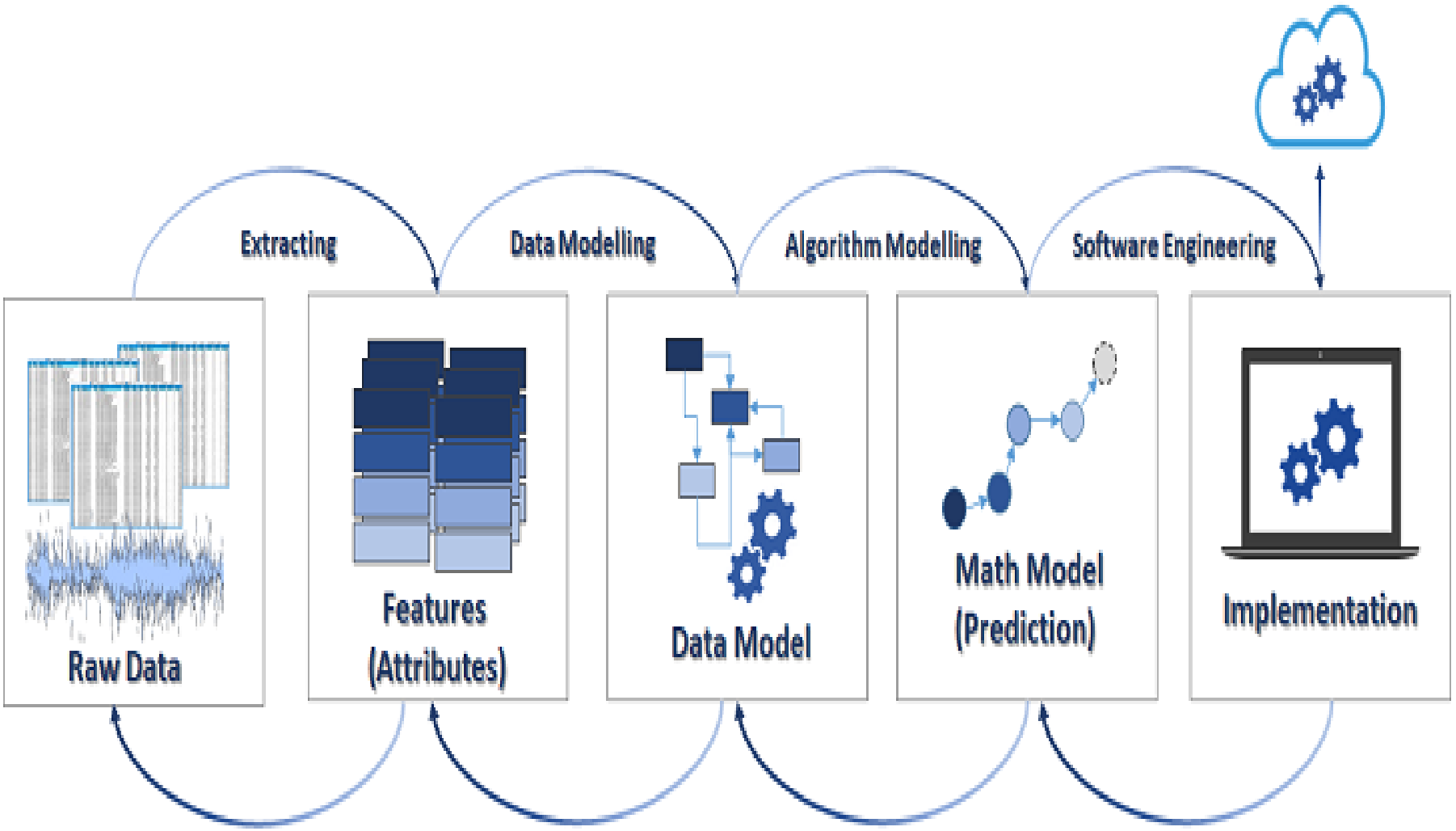
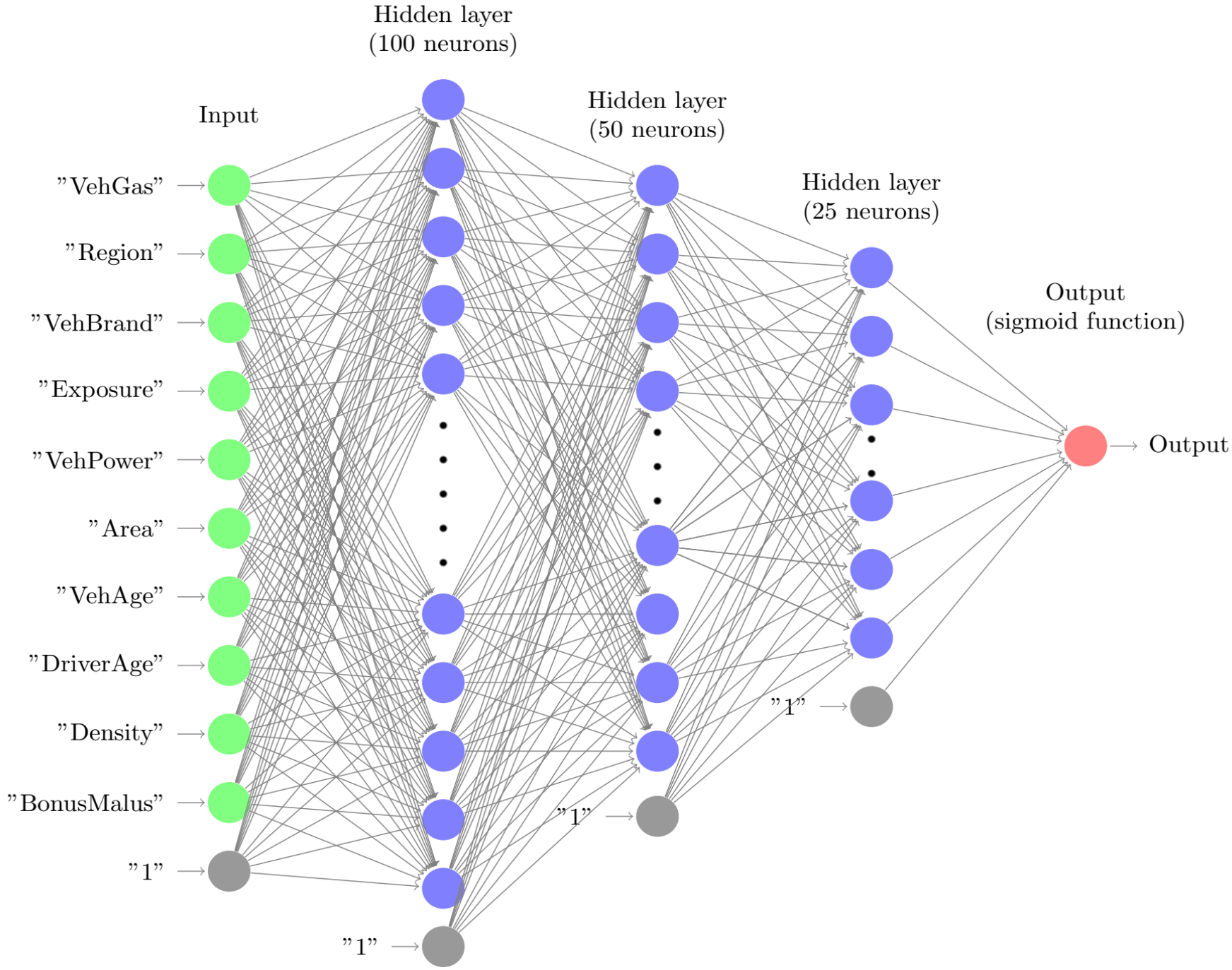
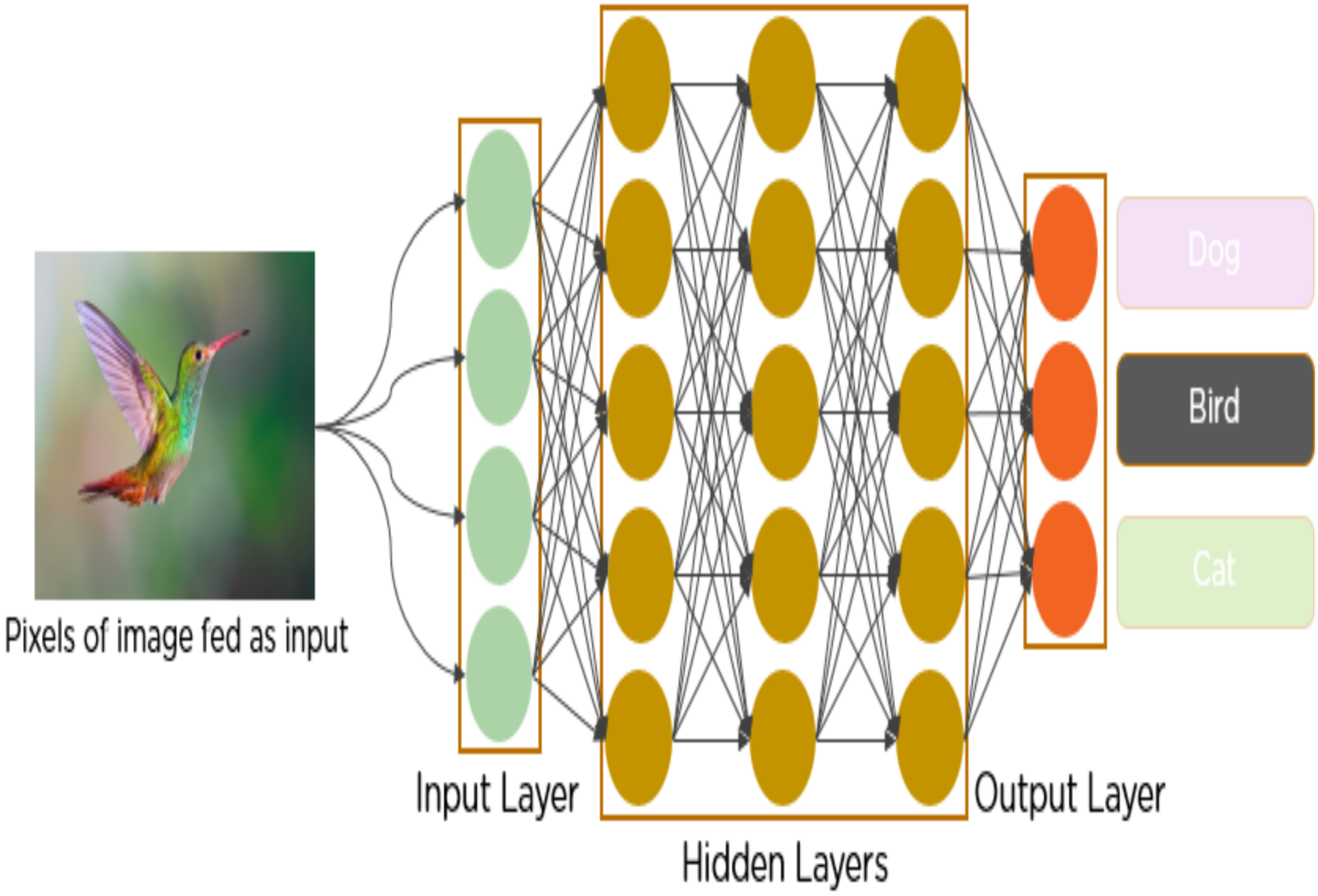


Figure 2: Example of a neural network for OCR.

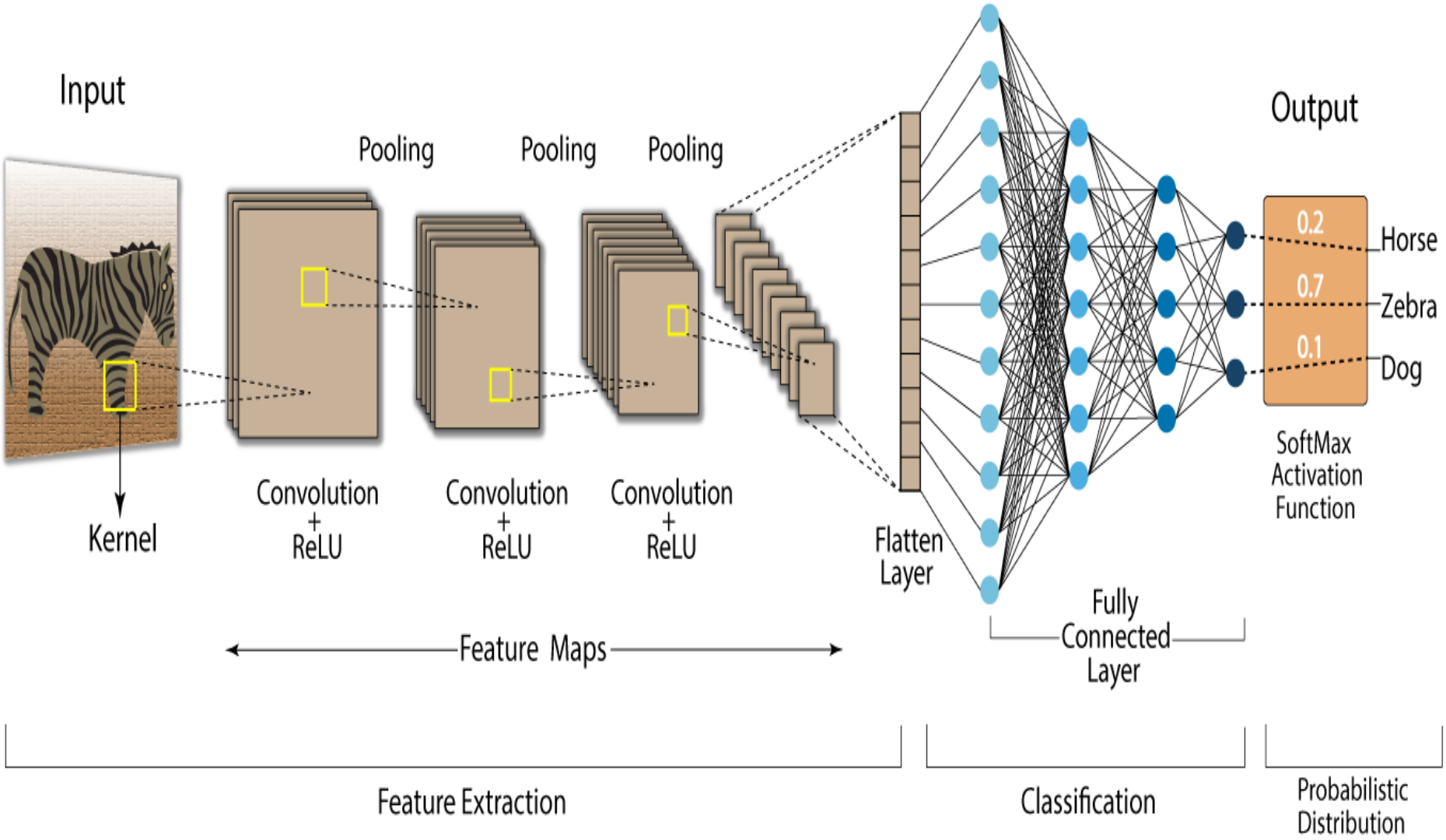
Deep Learning Modelling



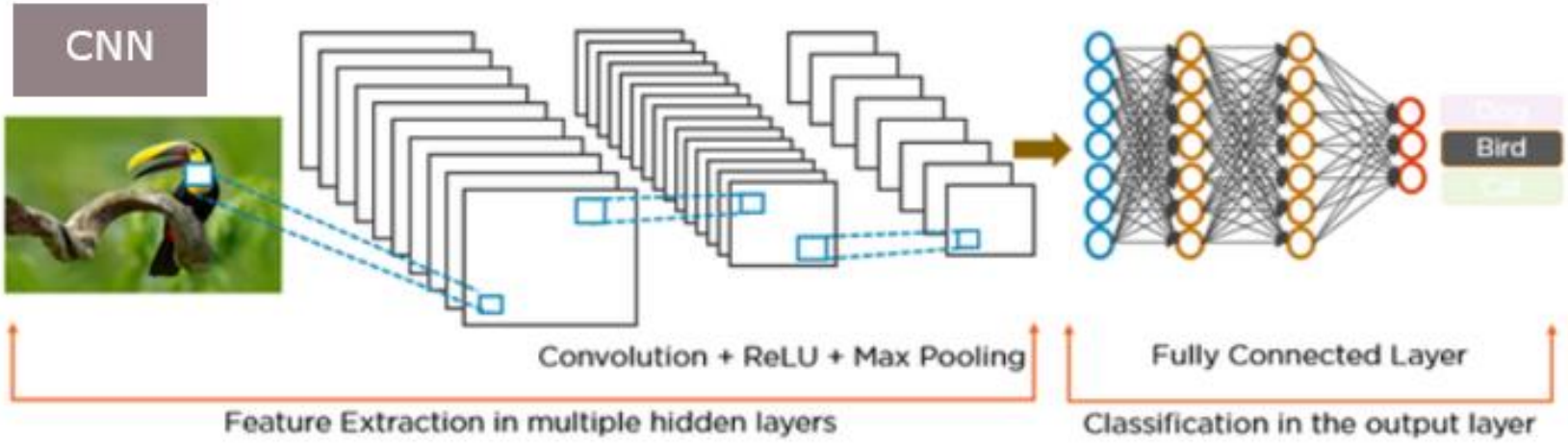

Hidden layer
(100 neurons)
Hidden layer
(50 neurons)
Hidden layer
(25 neurons)
Input
Output
(sigmoid function)
"VehGas"
"Region"
"VehBrand"
"Exposure"
"VehPower"
"Area"
"VehAge"
"DriverAge"
"Density"
"BonusMalus"
"1"
"1"
"1"
"1"
Output


Dog
Bird
Cat
Pixels of image fed as input
Input Layer
Hidden Layers
Output Layer

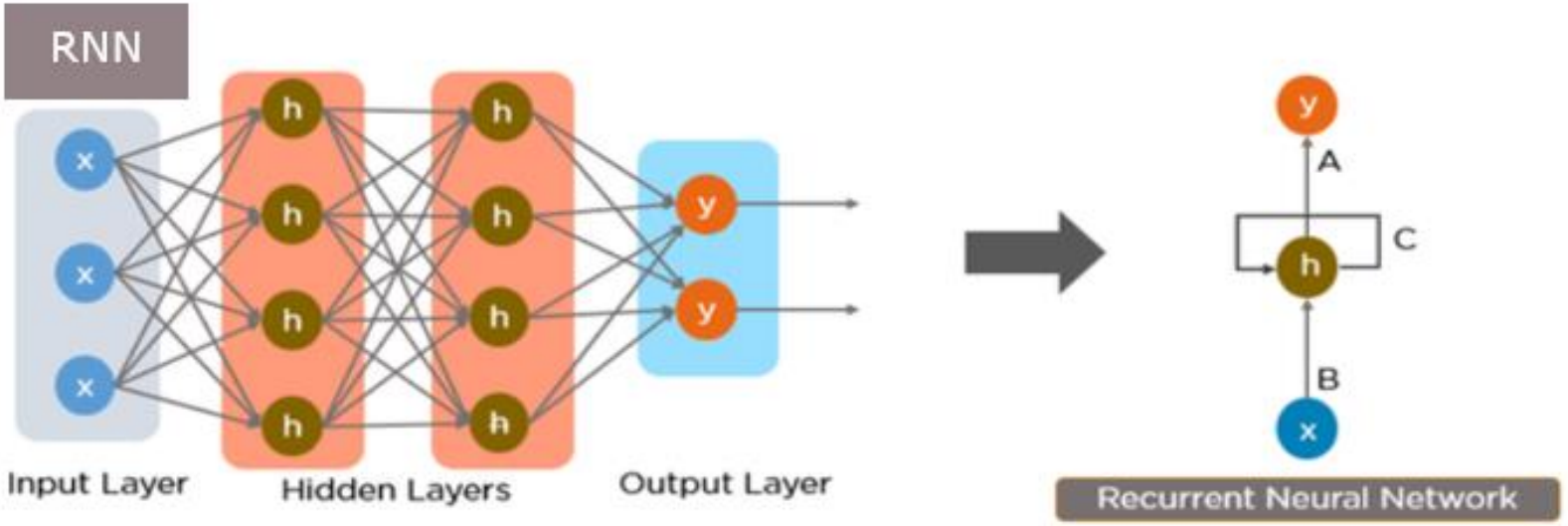
Convolution Neural Network (CNN)



Convolutional Neural Network

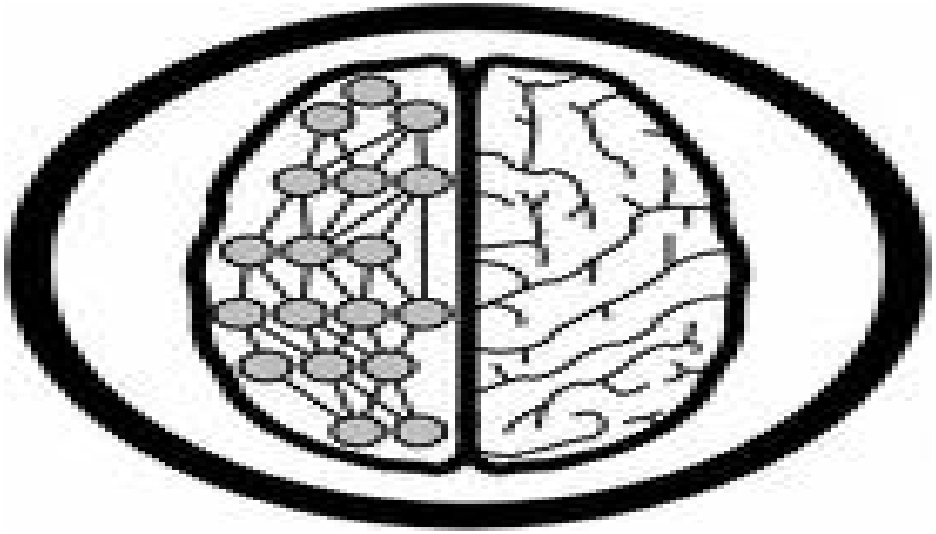


Recurrent Neural Network



How do ANNs work?

- An artificial neural network (ANN) is either a hardware implementation or a computer program which strives to simulate the information processing capabilities of its biological exemplar. ANNs are typically composed of a great number of interconnected artificial neurons. The artificial neurons are simplified models of their biological counterparts.
- ANN is a technique for solving problems by constructing software that works like our brains.

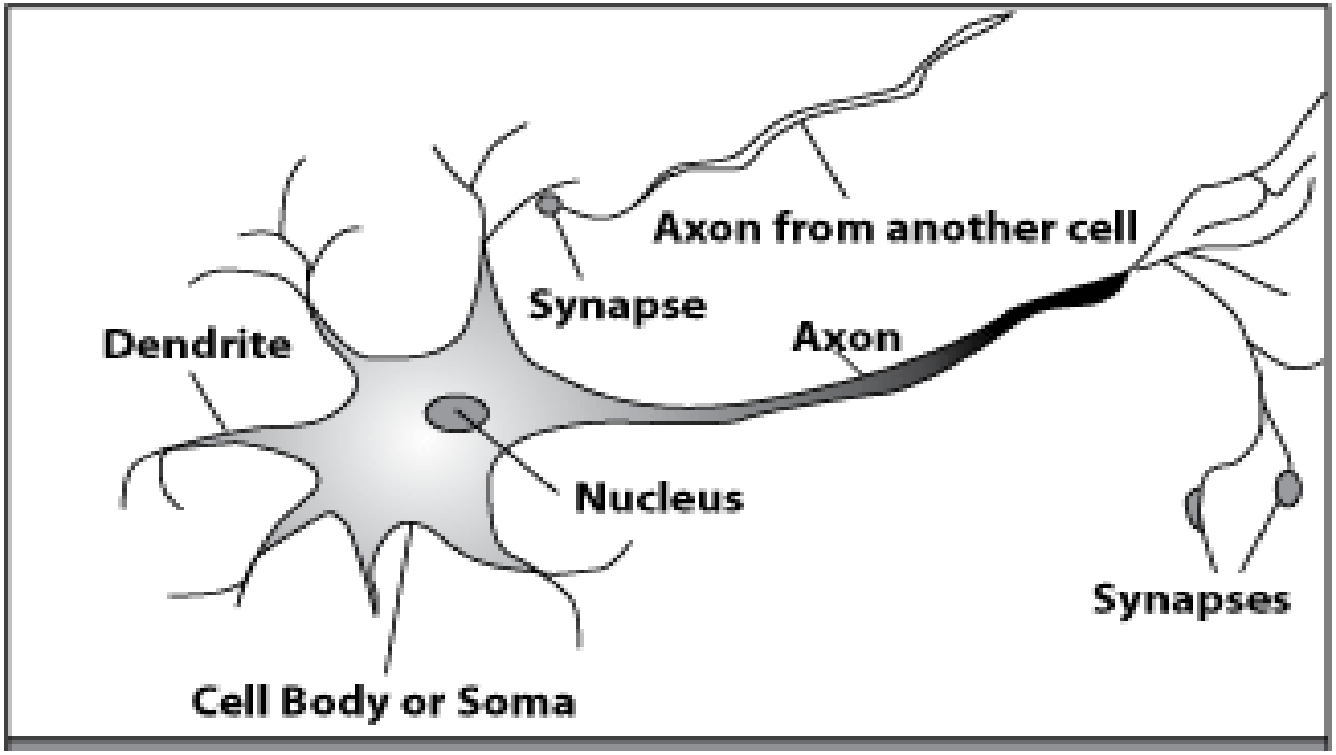


Characteristics of BNN and ANN

Characteristics	Biological Neural Network	Artificial Neural Network
Speed	Processes information at a slower rate. Response time is measured in milliseconds.	Information is processed at a faster rate. The response time is measured in nanoseconds.
Processing	Massively parallel processing.	Serial processing.
Size & Complexity	An extremely intricate and dense network of linked neurons of the order of 1011 neurons and 1015 interconnections.	Size and complexity are reduced. It is incapable of performing sophisticated pattern recognition tasks.
Storage	An extremely intricate and dense network of linked neurons with 1015 interconnections, including neurons on the order of 1011.	The term "replaceable information storage" refers to the practice of replacing fresh data with old data.
Fault tolerance	The fact that information storage is flexible means that new information may be added by altering the connectivity strengths without deleting existing information.	Intolerant of faults. In the event of a system failure, corrupt data cannot be recovered.
Control Mechanism	There is no unique control mechanism outside of the computational task.	Controlling computer activity is handled by a control unit.

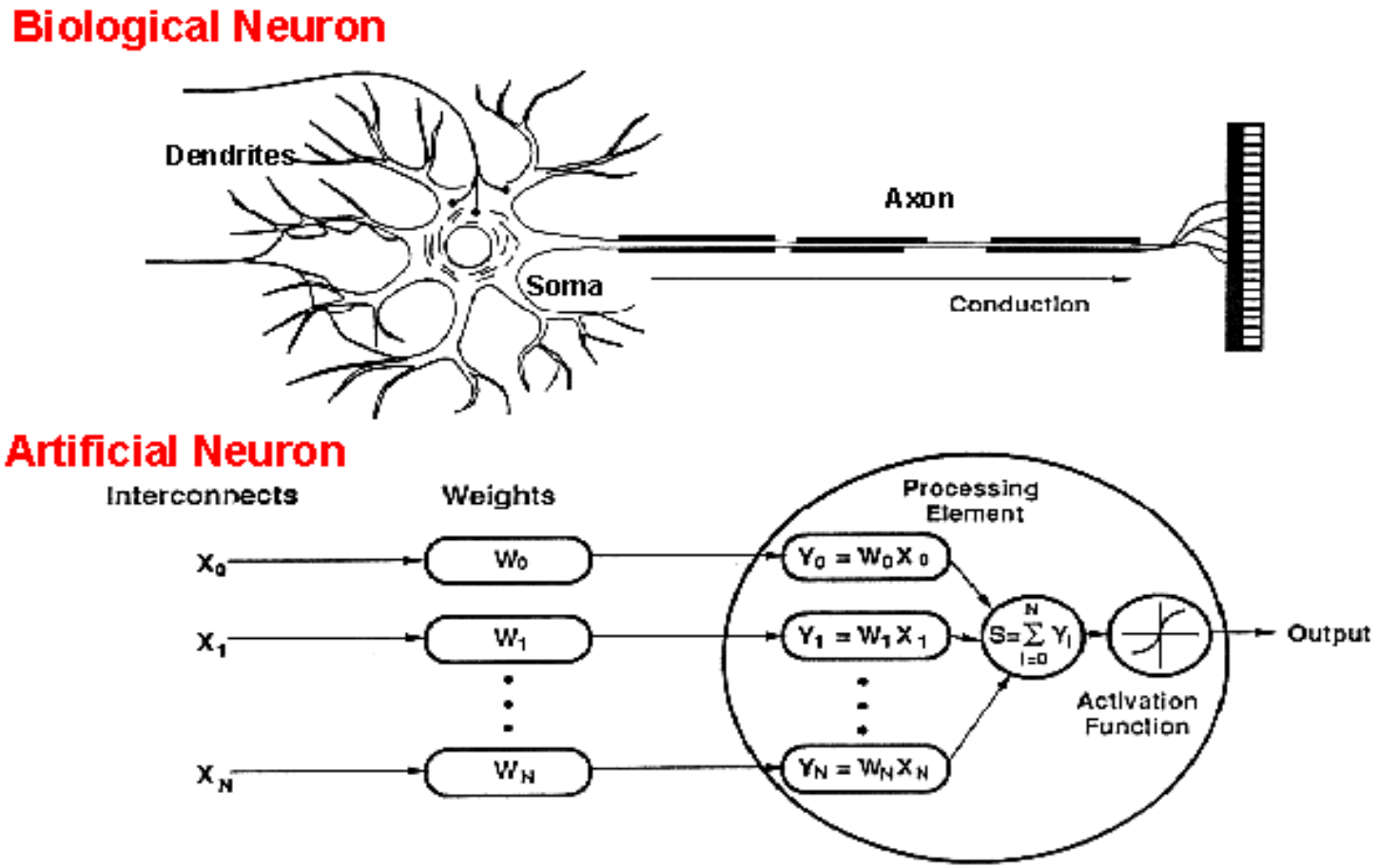
How do our brains work?

- A processing element



Dendrites: Input
Cell body: Processor
Synaptic: Link
Axon: Output

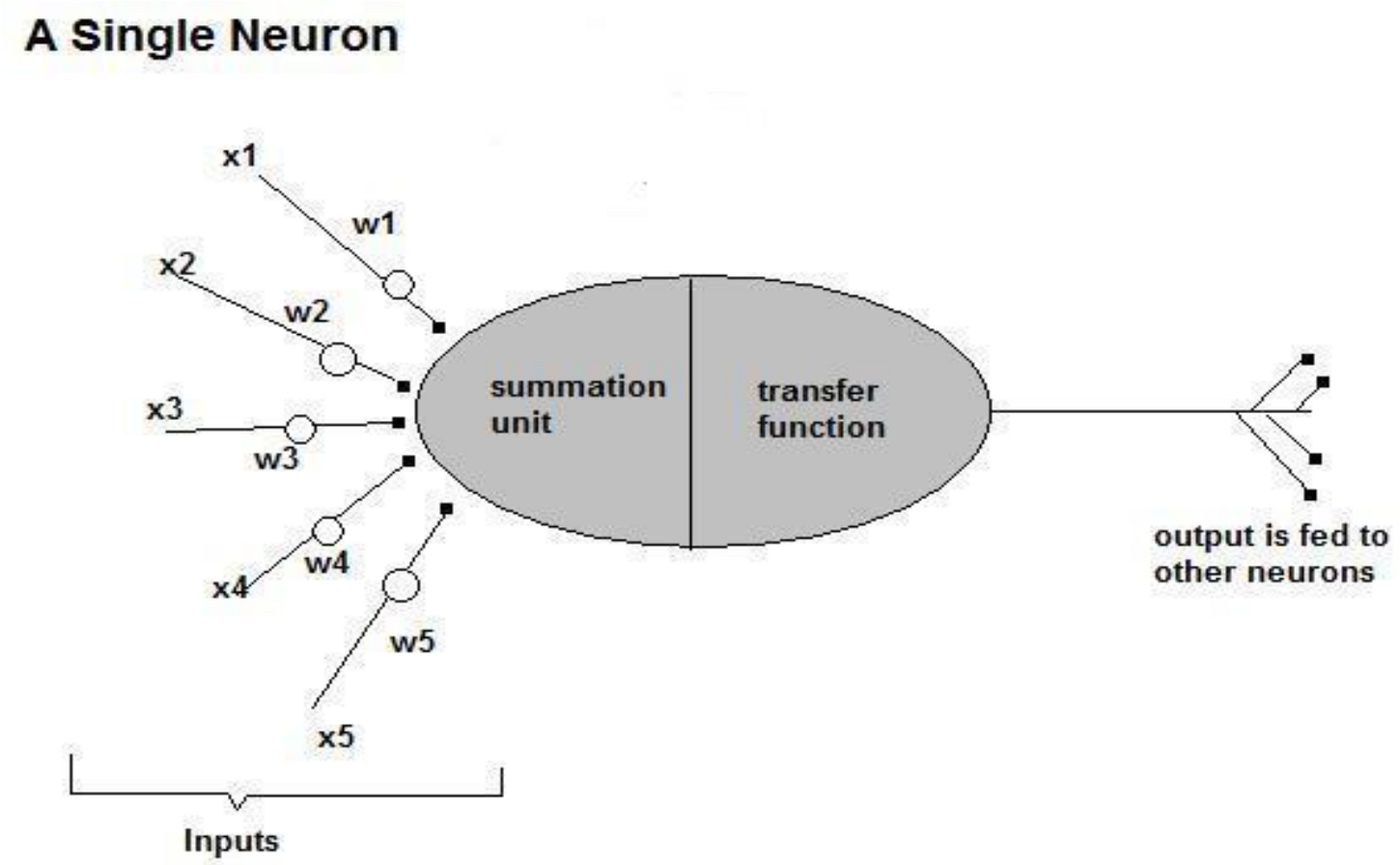
How do ANNs work?



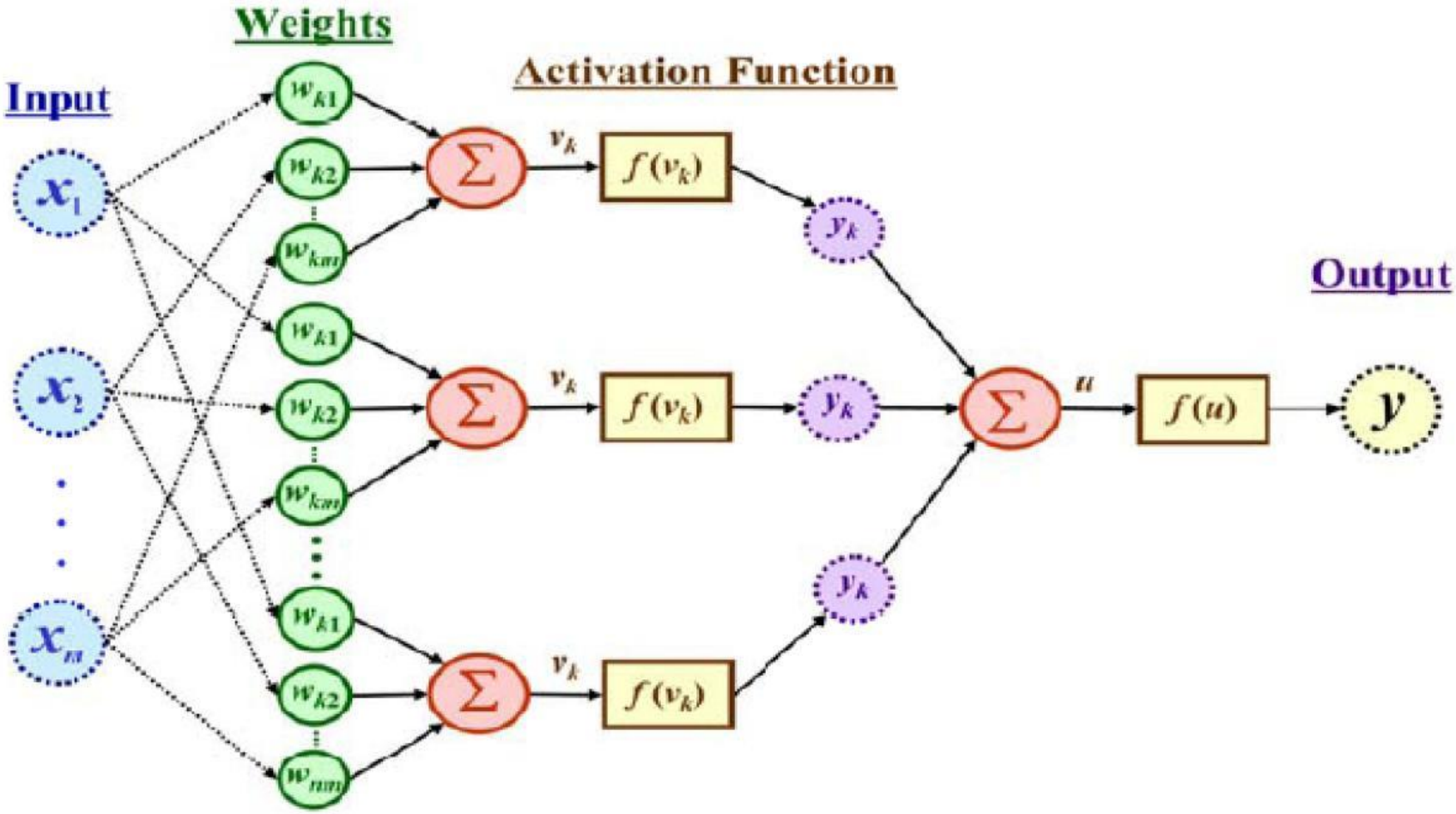
An artificial neuron is an imitation of a human neuron

How do ANNs work?

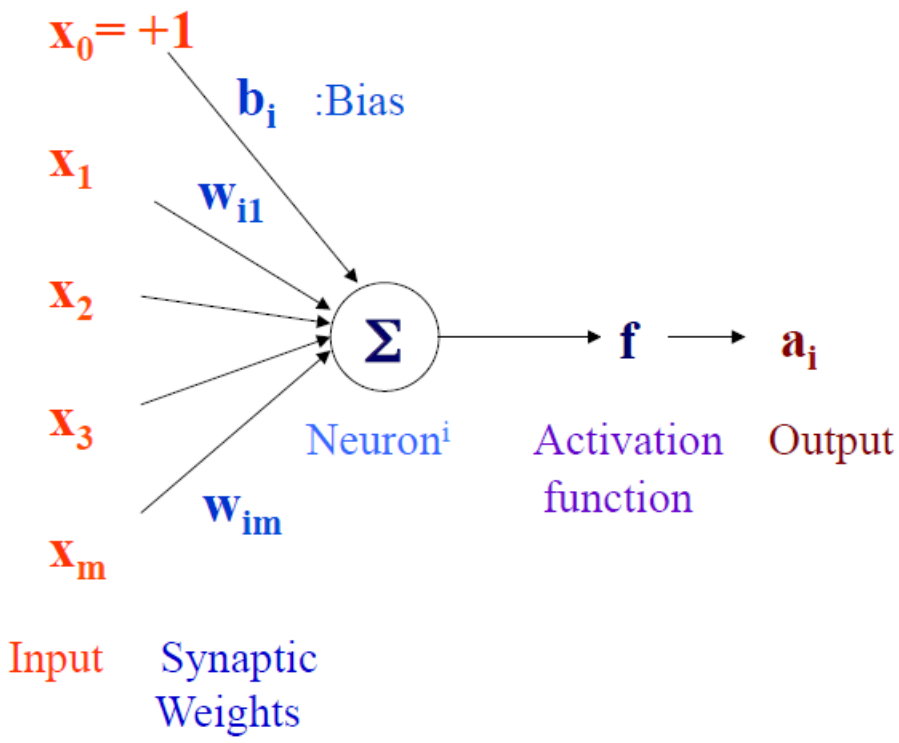
- Now, let us have a look at the model of an artificial neuron.



The output is a function of the input, that is affected by the weights, and the transfer functions



Artificial Neuron Model



Bias

$$a_i = f(n_i) = f\left(\sum_{j=1}^{n} w_{ij} x_j + b_i\right)$$

An artificial neuron:

- computes the weighted sum of its input (called its **net input**)
- adds its bias
- passes this value through an activation function

We say that the neuron "fires" (i.e. becomes active) if its output is above zero.

Bias

Bias can be incorporated as another weight clamped to a fixed input of +1.0

This extra free variable (bias) makes the neuron more powerful.

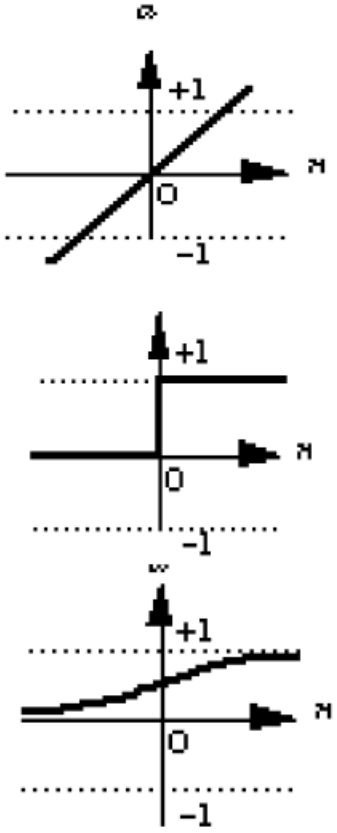
$$a_i = f(n_i) = f\left(\sum_{j=0}^{n} w_{ij} x_j\right) = f(\mathbf{w}_i . \mathbf{x}_j)$$

Activation functions

Also called the squashing function as it limits the amplitude of the output of the neuron.

Many types of activations functions are used:

- linear: $a = f(n) = n$
- threshold: (hardlimiting) $a = \{1 \text{ if } n >= 0$, $0 \text{ if } n < 0$
- sigmoid: $a = 1/(1+e^{-n})$
- ...



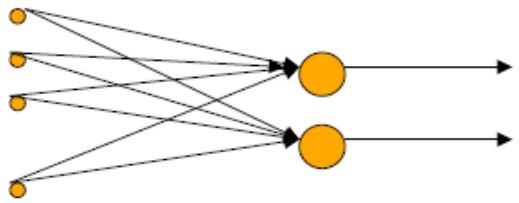
Activation Functions

Name	Input/Output Relation	Icon	MATLAB Function
Hard Limit	$a = 0 \quad n < 0$ $a = 1 \quad n \geq 0$		hardlim
Symmetrical Hard Limit	$a = -1 \quad n < 0$ $a = +1 \quad n \geq 0$		hardlims
Linear	$a = n$		purelin
Saturating Linear	$a = 0 \quad n < 0$ $a = n \quad 0 \leq n \leq 1$ $a = 1 \quad n > 1$		satlin
Symmetric Saturating Linear	$a = -1 \quad n < -1$ $a = n \quad -1 \leq n \leq 1$ $a = 1 \quad n > 1$		satlins
Log-Sigmoid	$a = \frac{1}{1 + e^{-n}}$		logsig
Hyperbolic Tangent Sigmoid	$a = \frac{e^{n} - e^{-n}}{e^{n} + e^{-n}}$		tansig
Positive Linear	$a = 0 \quad n < 0$ $a = n \quad 0 \leq n$		poslin
Competitive	$a = 1$ neuron with max n $a = 0$ all other neurons		compet

Different Network Topologies

Single layer feed-forward networks

- Input layer projecting into the output layer



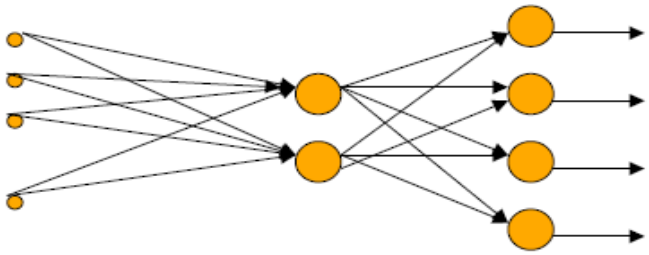
Input layer

Output layer

Different Network Topologies

Multi-layer feed-forward networks

- One or more hidden layers.
- Input projects only from previous layers onto a layer.
  typically, only from one layer to the next



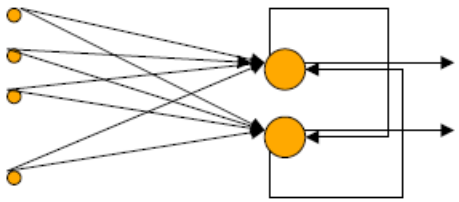
Input layer Hidden layer Output layer

2-layer or
1-hidden layer
fully connected
network

Different Network Topologies

Recurrent networks

- A network with feedback, where some of its inputs are connected to some of its outputs (discrete time).



Input layer

Output layer

Multilayer Perceptron

Each layer may have different number of nodes and different activation functions

But commonly:

- **Same activation function within one layer**
  - sigmoid/tanh activation function is used in the hidden units, and
  - sigmoid/tanh or linear activation functions are used in the output units depending on the problem (classification-sigmoid/tanh or function approximation-linear)

Artificial Neural Networks

- An ANN can:
  1. compute *any computable* function, by the appropriate selection of the network topology and weights values.
  2. learn from experience!
     - Specifically, by trial-and-error

Which framework should you use?

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Which framework should you use?

TensorFlow has implemented various levels of abstraction to make implementation easy. This also makes debugging easy

It is simple and easy, but not as fast as TensorFlow. It is more user-friendly than any other deep learning API

It is the preferred deep learning API for teachers but is not as widely used in production as TensorFlow. Faster, but lower GPU utilization

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