Introduction to Big Data and Deep Learning

12-Sep, 2023

Data Science Program

Master, RUPP

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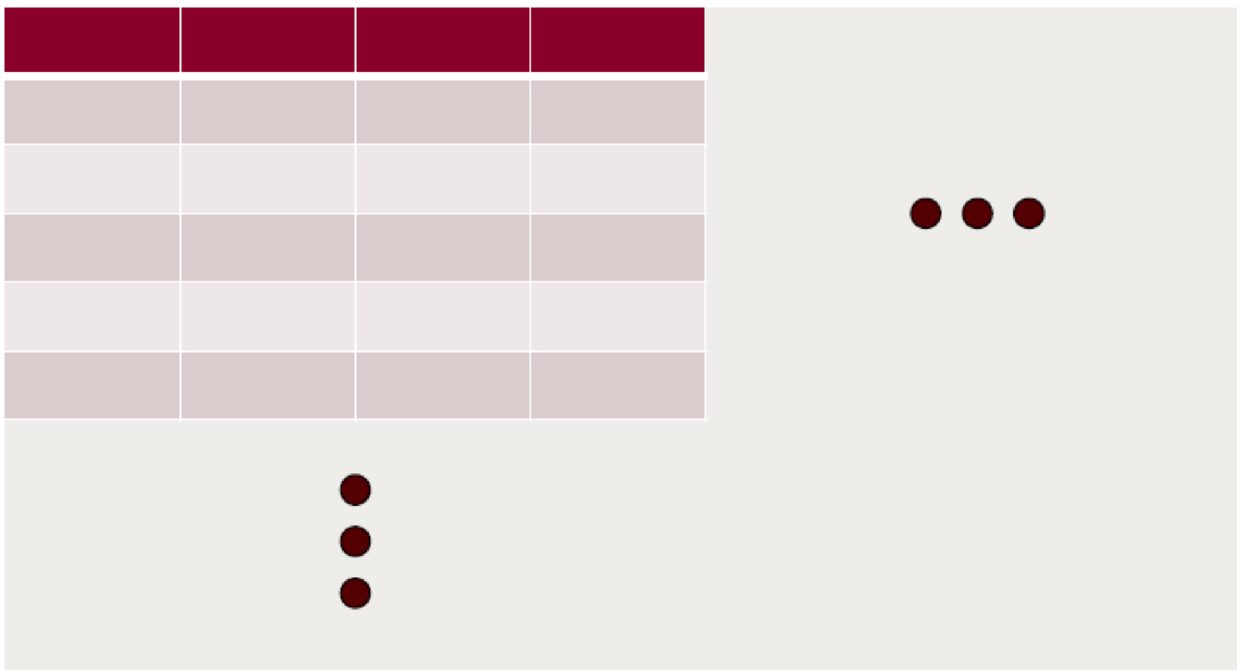
Schedule

#	Date	Topic
1	12-Sep	Introduction of Big Data and Deep Learning
2	13-Sep	Mathematical preparation
3	14-Sep	Big Data
4	15-Sep	Deep Learning
5	16-Sep	(9:00-) Deep Learning 2
6	18-Sep	Reinforcement Learning

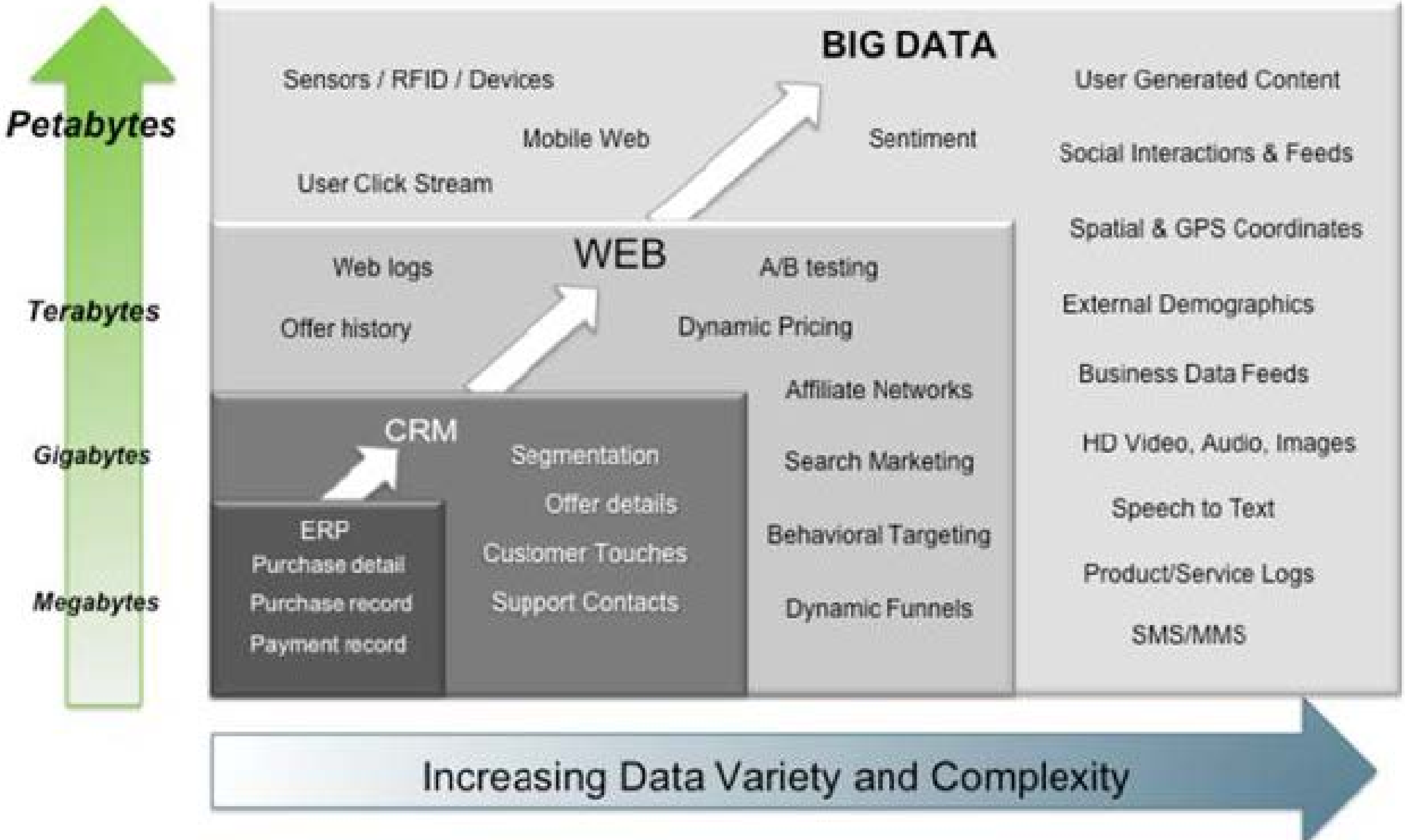
Importantly, for the course of Big Data and Deep Learning, we will not contain distributed database and networks, which will be needed for *very big data*.

What is Big Data?

- In a narrow sense, Big Data means only sample size.
- In a broad sense, Big Data represents both sample size and dimensionality.



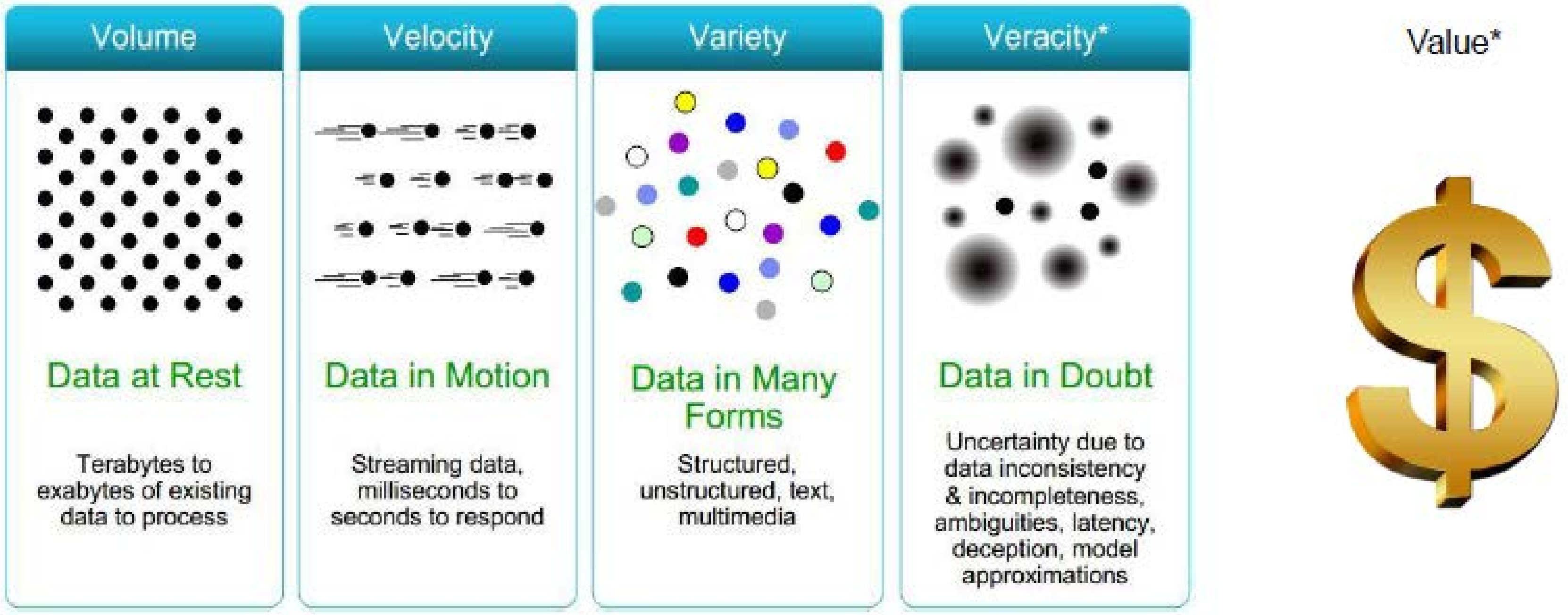
3V's (Volume, Velocity, and Variety)



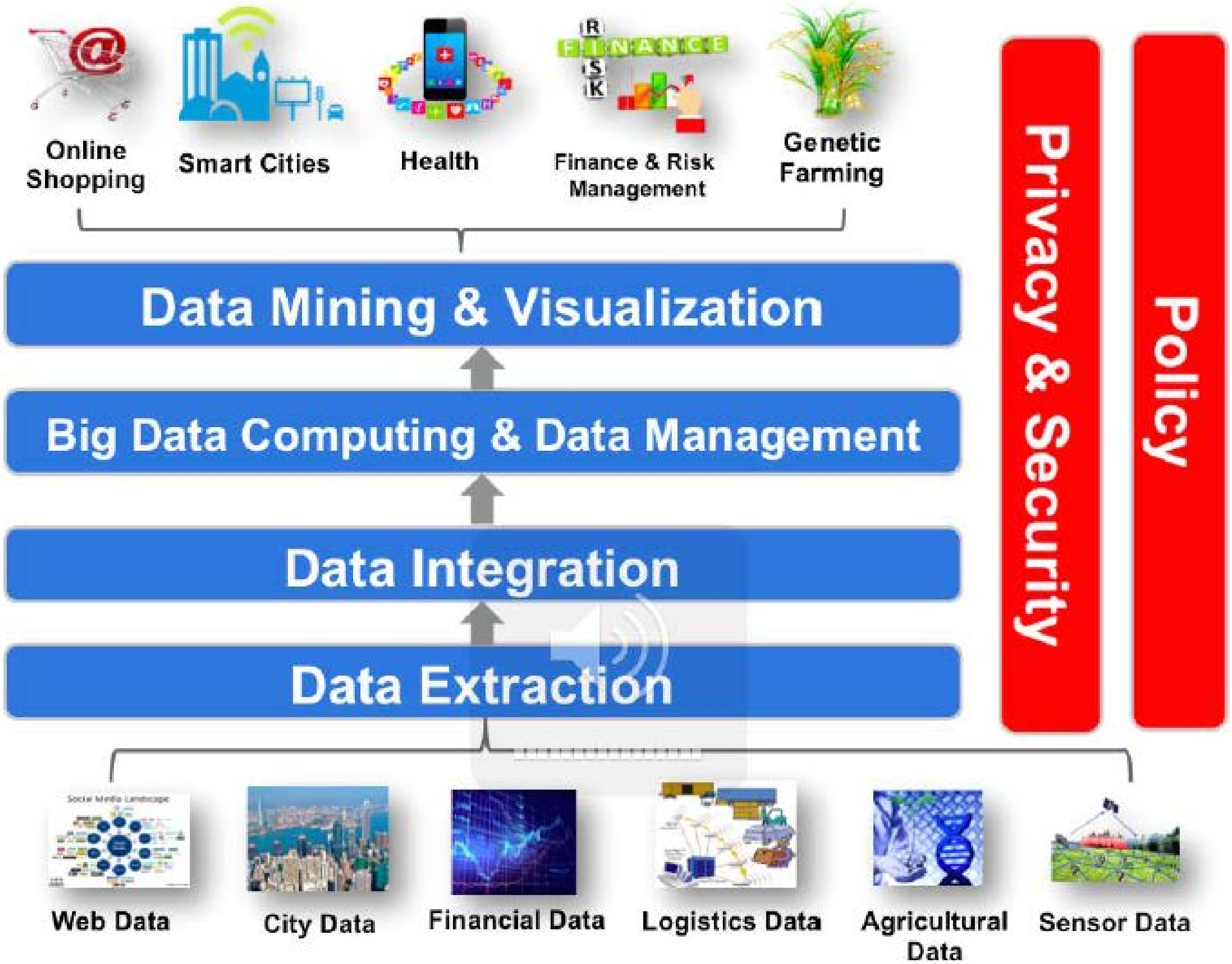
Source: *Contents of above graphic created in partnership with Teradata, Inc.*

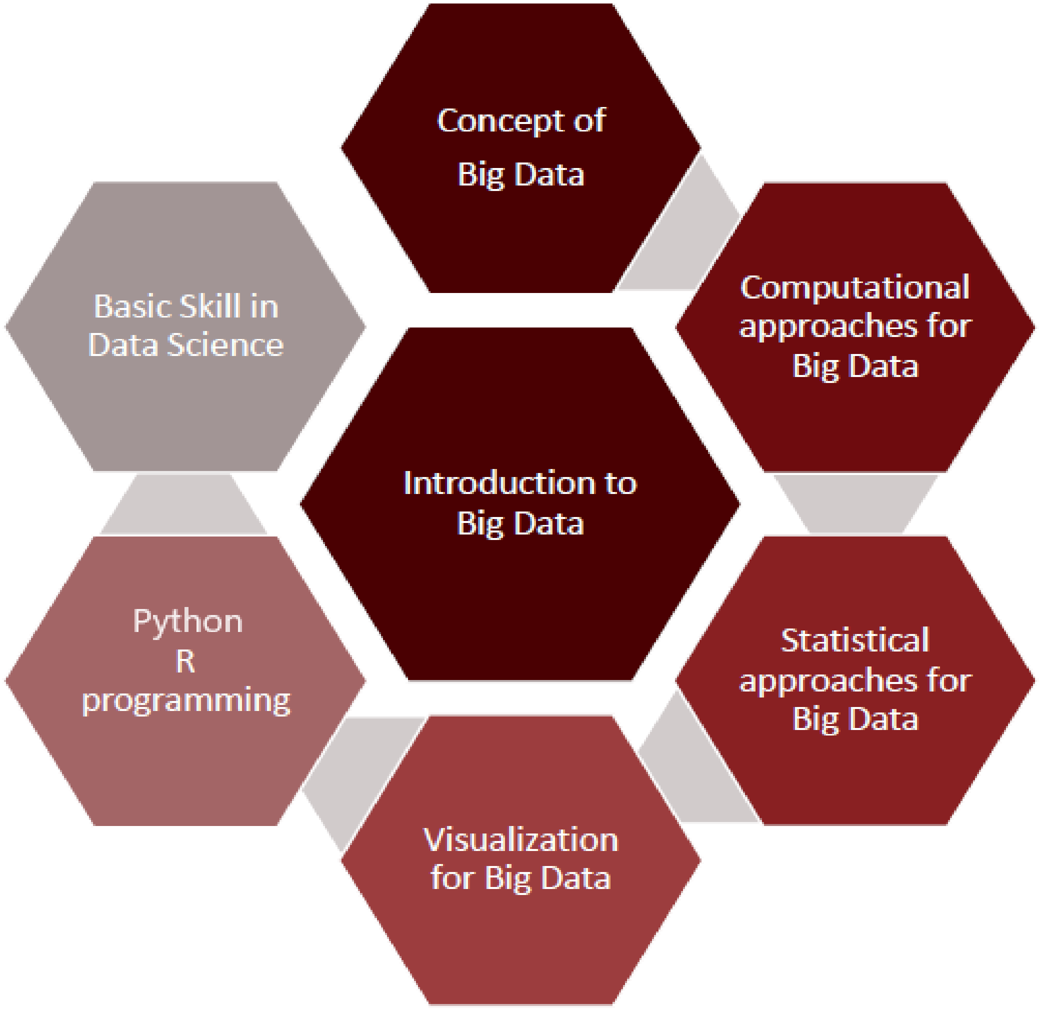
5V's (Volume, Velocity, Variety, Veracity, and Value)

- Volume: Data Size
- Velocity: Data production speed
- Variety: Data oriented from various/different sources
- Veracity: Data accuracy (Trustworthiness)
- Value: Data Value



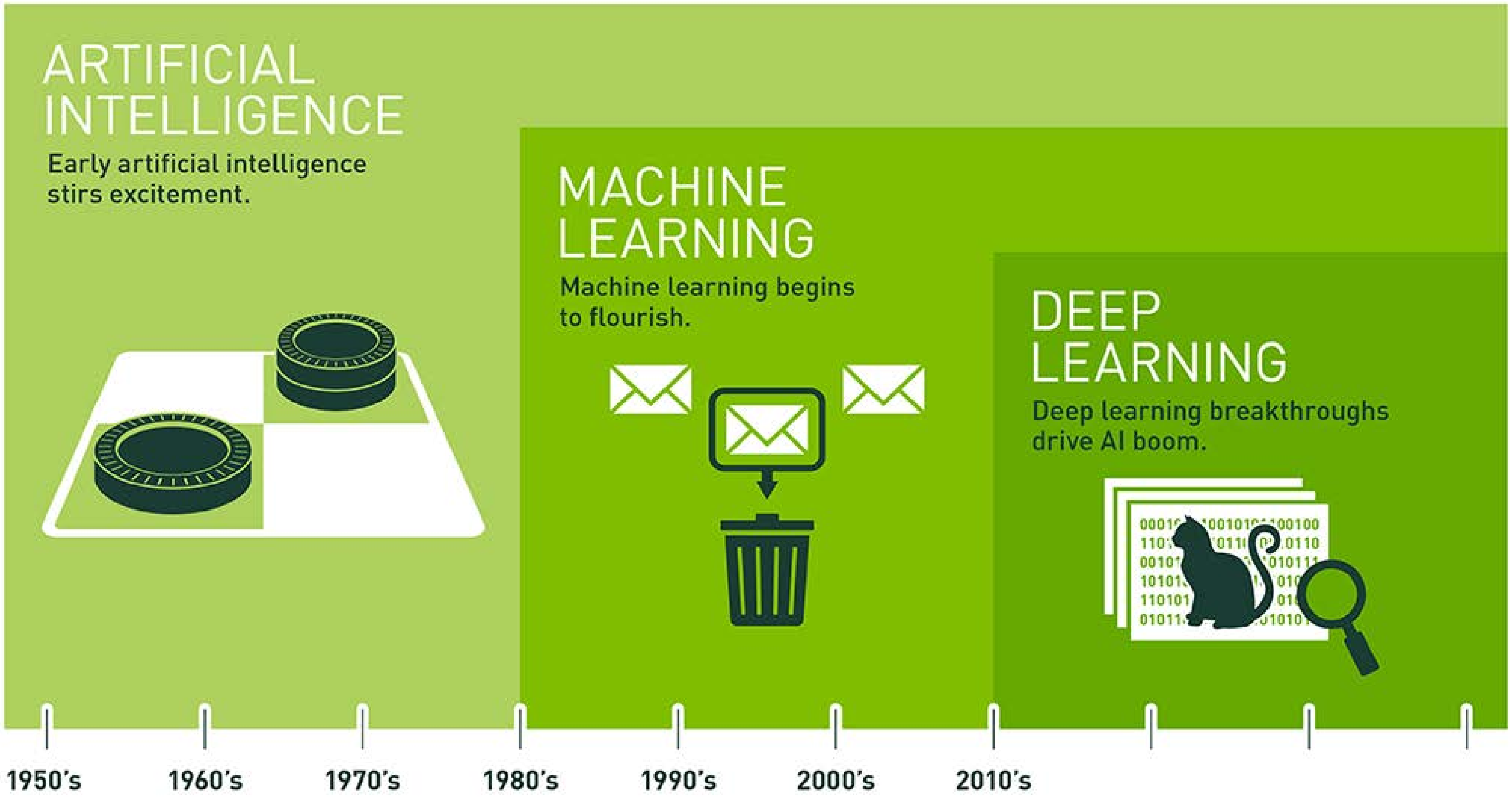
- Big Data can bring “**big values**” to our life in almost every aspects.
- Technologically, Big Data is bringing about changes in our lives because it allows **diverse and heterogeneous data to be fully integrated and analyzed to help us make decisions**.
- Today, with the Big Data technology, **thousands of data from seemingly unrelated areas can help support important decisions**. This is the power of Big Data.
- Areas of Applications
  - Health and Well being
  - Policy making and public opinions
  - Smart cities and more efficient society
  - New online educational models: MOOC and Student-Teacher modeling
  - Robotics and human-robot interaction
- Much of this power hinges on Research on Analytics


Online Shopping
Smart Cities
Health
Finance & Risk Management
Genetic Farming
Data Mining & Visualization
Big Data Computing & Data Management
Data Integration
Data Extraction
Privacy & Security
Policy
Web Data
City Data
Financial Data
Logistics Data
Agricultural Data
Sensor Data


Concept of
Big Data
Basic Skill in
Data Science
Computational
approaches for
Big Data
Introduction to
Big Data
Python
R
programming
Statistical
approaches for
Big Data
Visualization
for Big Data

Deep Learning

- Deep Learning is a subfield of Machine Learning that involves the use of neural networks to model and solve complex problems. Neural networks are modeled after the structure and function of the human brain and consist of layers of interconnected nodes that process and transform data.
  1. The key characteristic of Deep Learning is the use of deep neural networks, which have multiple layers of interconnected nodes. These networks can learn complex representations of data by discovering hierarchical patterns and features in the data. Deep Learning algorithms can automatically learn and improve from data without the need for manual feature engineering.
  2. Deep Learning has achieved significant success in various fields, including image recognition, natural language processing, speech recognition, and recommendation systems. Some of the popular Deep Learning architectures include Convolutional Neural Networks (CNNs), Recurrent Neural Networks (RNNs), and Deep Belief Networks (DBNs).
  3. Training deep neural networks typically requires a large amount of data and computational resources. However, the availability of cloud computing and the development of specialized hardware, such as Graphics Processing Units (GPUs), has made it easier to train deep neural networks.

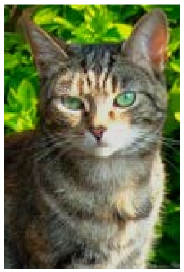


Since an early flush of optimism in the 1950s, smaller subsets of artificial intelligence – first machine learning, then deep learning, a subset of machine learning – have created ever larger disruptions.

Image from https://blogs.nvidia.com/blog/2016/07/29/whats-difference-artificial-intelligence-machine-learning-deep-learning-ai/

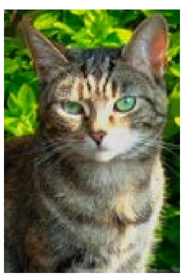
Traditional ML and DL

"Traditional" machine learning:



handcrafted features → learned classifier → **cat**

Deep, "end-to-end" learning:



learned low-level features → learned mid-level features → learned high-level features → learned classifier → **cat**

More in detail

Traditional Machine Learning	Deep Learning
Apply statistical algorithms to learn the hidden patterns and relationships in the dataset.	Uses artificial neural network architecture to learn the hidden patterns and relationships in the dataset.
Can work on the smaller amount of dataset	Requires the larger volume of dataset compared to machine learning
Better for the low-label task.	Better for complex task like image processing, natural language processing, etc.
Takes less time to train the model.	Takes more time to train the model.
A model is created by relevant features which are manually extracted from images to detect an object in the image.	Relevant features are automatically extracted from images. It is an end-to-end learning process.
Less complex and easy to interpret the result.	More complex, it works like the black box interpretations of the result are not easy.
It can work on the CPU or requires less computing power as compared to deep learning.	It requires a high-performance computer with GPU.

Challenges in Deep Learning

- Deep learning has made significant advancements in various fields, but there are still some challenges that need to be addressed. Here are some of the main challenges in deep learning:

1. Data availability: It requires large amounts of data to learn from. For using deep learning it's a big concern to gather as much data for training.
2. Computational Resources: For training the deep learning model, it is computationally expensive because it requires specialized hardware like GPUs and TPUs.
3. Time-consuming: While working on sequential data depending on the computational resource it can take very large even in days or months.
4. Interpretability: Deep learning models are complex, it works like a black box. it is very difficult to interpret the result.
5. Overfitting: when the model is trained again and again, it becomes too specialized for the training data, leading to overfitting and poor performance on new data.

Advantages of Deep Learning

1. High accuracy: Deep Learning algorithms can achieve state-of-the-art performance in various tasks, such as image recognition and natural language processing.
2. Automated feature engineering: Deep Learning algorithms can automatically discover and learn relevant features from data without the need for manual feature engineering.
3. Scalability: Deep Learning models can scale to handle large and complex datasets, and can learn from massive amounts of data.
4. Flexibility: Deep Learning models can be applied to a wide range of tasks and can handle various types of data, such as images, text, and speech.
5. Continual improvement: Deep Learning models can continually improve their performance as more data becomes available.

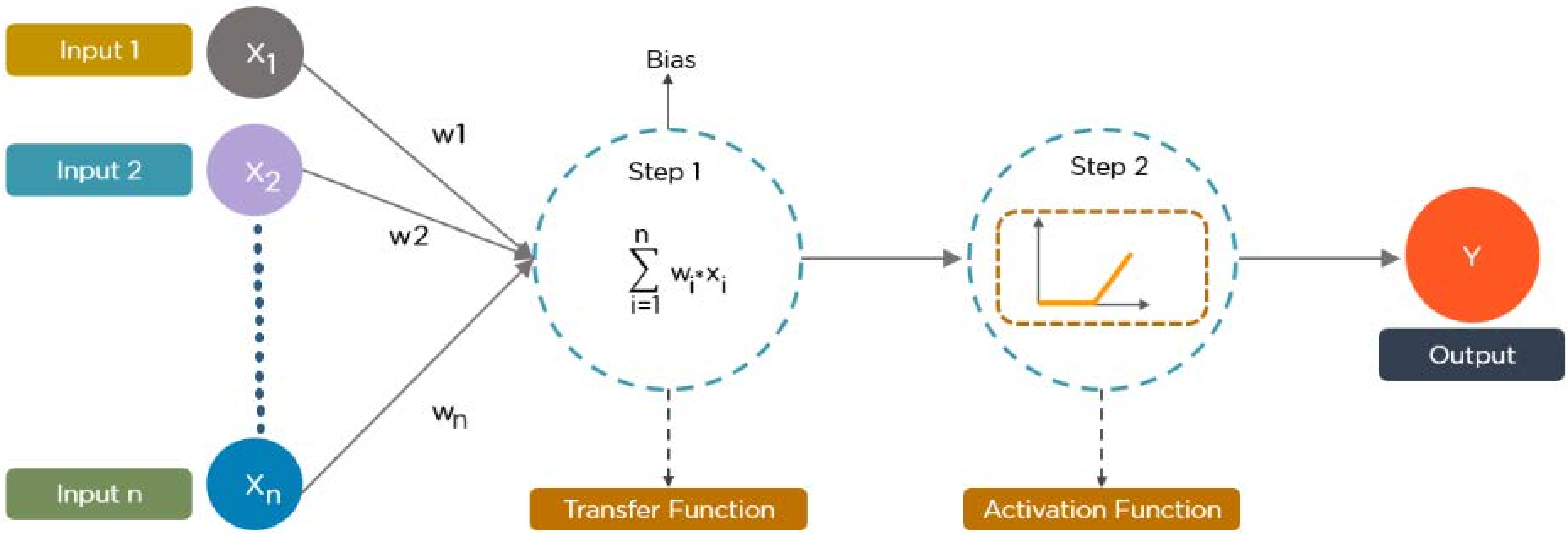
Disadvantages of Deep Learning

1. High computational requirements: Deep Learning models require large amounts of data and computational resources to train and optimize.
2. Requires large amounts of labeled data: Deep Learning models often require a large amount of labeled data for training, which can be expensive and time- consuming to acquire.
3. Interpretability: Deep Learning models can be challenging to interpret, making it difficult to understand how they make decisions.
4. Overfitting: Deep Learning models can sometimes overfit to the training data, resulting in poor performance on new and unseen data.
5. Black-box nature: Deep Learning models are often treated as black boxes, making it difficult to understand how they work and how they arrived at their predictions.

In summary, while Deep Learning offers many advantages, including high accuracy and scalability, it also has some disadvantages, such as high computational requirements, the need for large amounts of labeled data, and interpretability challenges. These limitations need to be carefully considered when deciding whether to use Deep Learning for a specific task.

Defining Neural Networks

- A neural network is structured like the human brain and consists of artificial neurons, also known as nodes. These nodes are stacked next to each other in three layers:
  - The input layer
  - The hidden layer(s)
  - The output layer
- Data provides each node with information in the form of inputs. The node multiplies the inputs with random weights, calculates them, and adds a bias. Finally, nonlinear functions, also known as activation functions, are applied to determine which neuron to fire.



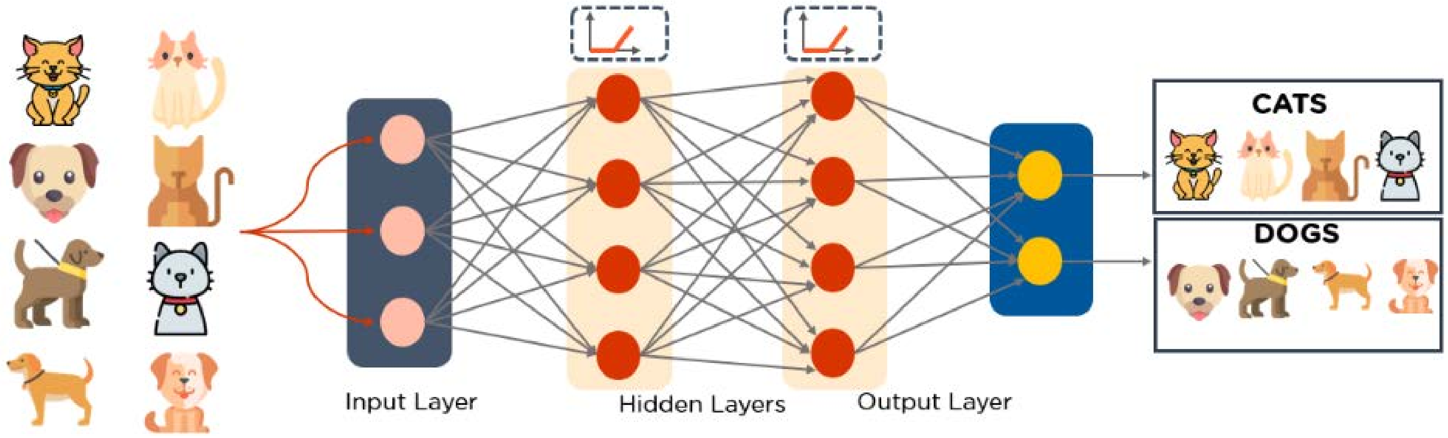
Types of Algorithms

1. Multilayer Perceptrons (MLPs)
2. Convolutional Neural Networks (CNNs)
3. Recurrent Neural Networks (RNNs)
4. Long Short Term Memory Networks (LSTMs)
5. Generative Adversarial Networks (GANs)
6. Autoencoders
7. Deep Reinforcement Learning

And many more…

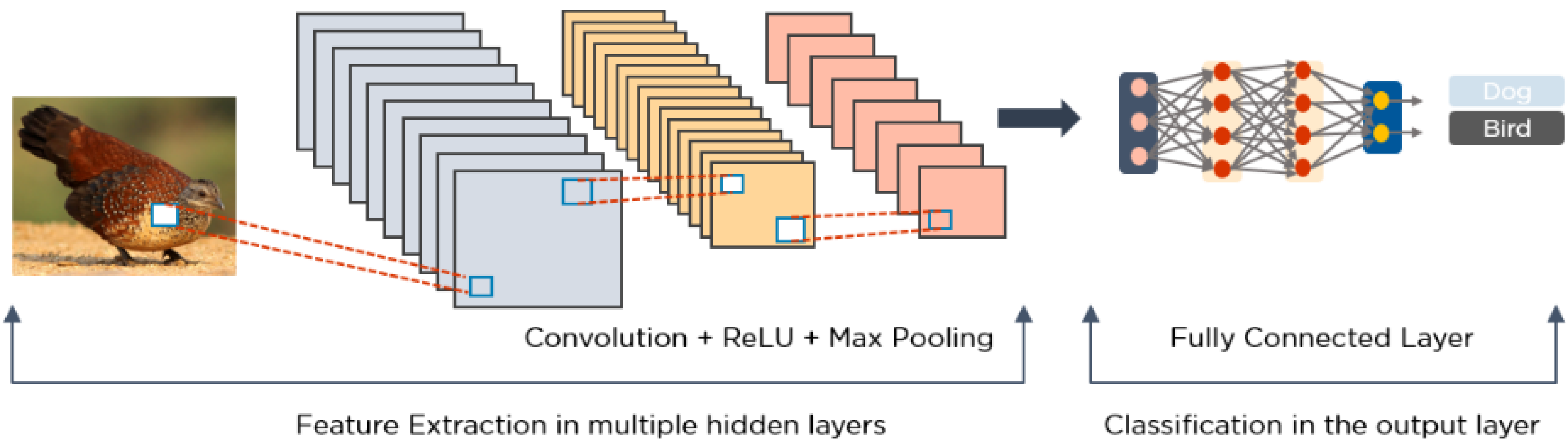
Multi-Layer Perceptrons (MLPs)

- MLPs are an excellent place to start learning about deep learning technology.
- MLPs belong to the class of feedforward neural networks with multiple layers of perceptrons that have activation functions. MLPs consist of an input layer and an output layer that are fully connected. They have the same number of input and output layers but may have multiple hidden layers and can be used to build speech-recognition, image-recognition, and machine-translation software.
- How Do MLPs Work?
  - MLPs feed the data to the input layer of the network. The layers of neurons connect in a graph so that the signal passes in one direction.
  - MLPs compute the input with the weights that exist between the input layer and the hidden layers.
  - MLPs use activation functions to determine which nodes to fire. Activation functions include ReLUs, sigmoid functions, and tanh.
  - MLPs train the model to understand the correlation and learn the dependencies between the independent and the target variables from a training data set.



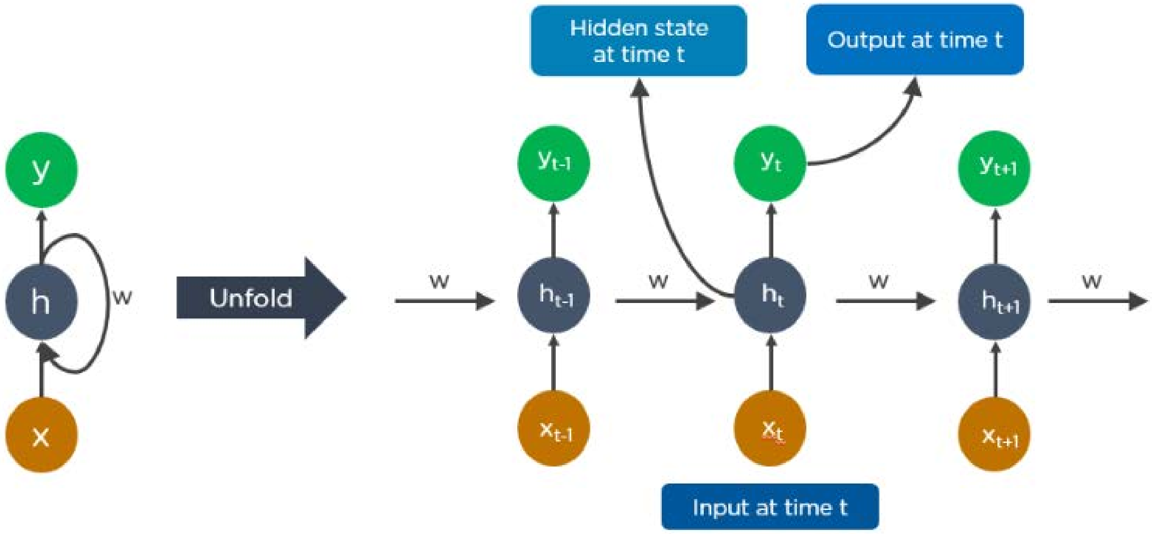
Convolutional Neural Networks (CNN)

- How Do CNNs Work?
  - CNN's have multiple layers that process and extract features from data:
- Convolution Layer
  - CNN has a convolution layer that has several filters to perform the convolution operation.
- Rectified Linear Unit (ReLU)
  - CNN's have a ReLU layer to perform operations on elements. The output is a rectified feature map.
- Pooling Layer
  - The rectified feature map next feeds into a pooling layer. Pooling is a down-sampling operation that reduces the dimensions of the feature map.
  - The pooling layer then converts the resulting two-dimensional arrays from the pooled feature map into a single, long, continuous, linear vector by flattening it.
- Fully Connected Layer
  - A fully connected layer forms when the flattened matrix from the pooling layer is fed as an input, which classifies and identifies the images.



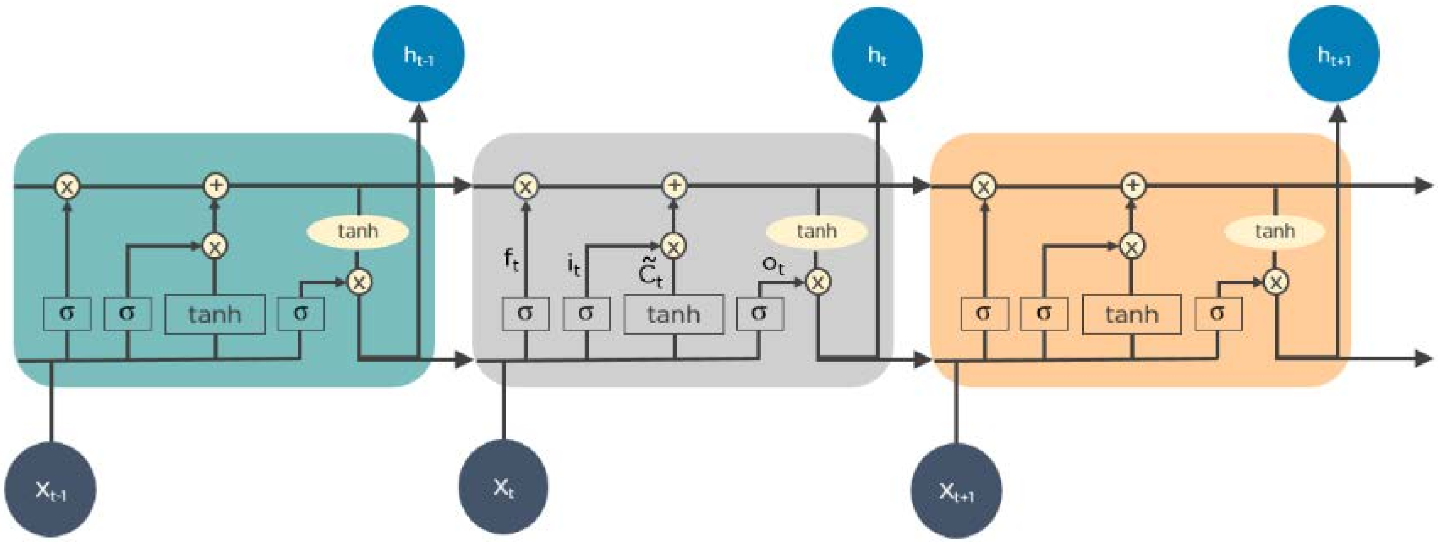
Recurrent Neural Networks (RNNs)

- RNNs have connections that form directed cycles, which allow the outputs from the LSTM to be fed as inputs to the current phase.
- The output from the LSTM becomes an input to the current phase and can memorize previous inputs due to its internal memory. RNNs are commonly used for image captioning, time-series analysis, natural-language processing, handwriting recognition, and machine translation.
- How Do RNNs work?
  - The output at time t-1 feeds into the input at time t.
  - Similarly, the output at time t feeds into the input at time t+1.
  - RNNs can process inputs of any length.
  - The computation accounts for historical information, and the model size does not increase with the input size.



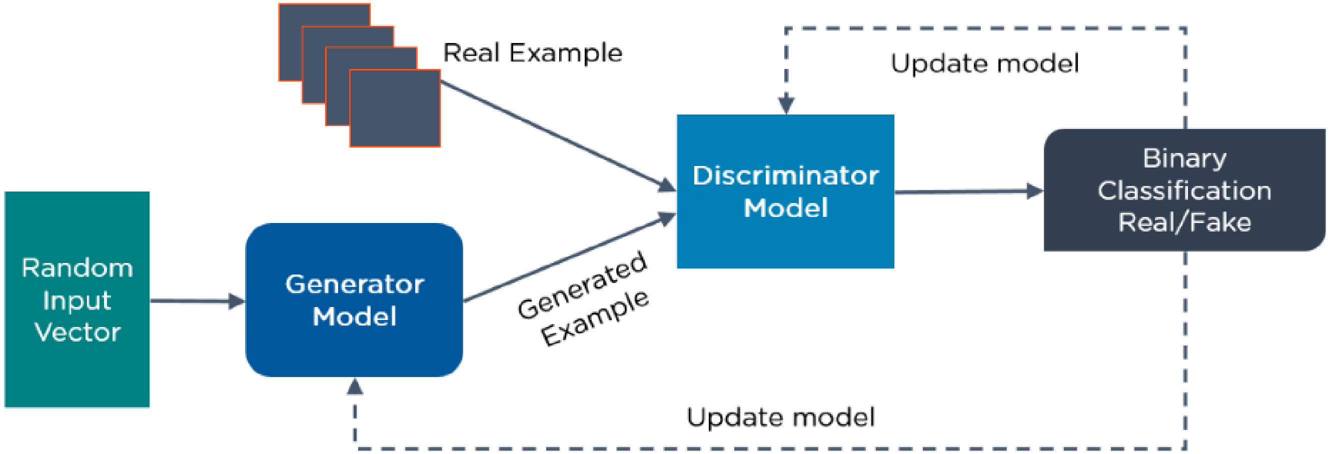
Long Short-Term Memory (LSTMs)

- LSTMs are a type of Recurrent Neural Network (RNN) that can learn and memorize long-term dependencies. Recalling past information for long periods is the default behavior.
- LSTMs retain information over time. They are useful in time-series prediction because they remember previous inputs. LSTMs have a chain-like structure where four interacting layers communicate in a unique way. Besides time-series predictions, LSTMs are typically used for speech recognition, music composition, and pharmaceutical development.
- How Do LSTMs Work?
  - First, they forget irrelevant parts of the previous state
  - Next, they selectively update the cell-state values
  - Finally, the output of certain parts of the cell state



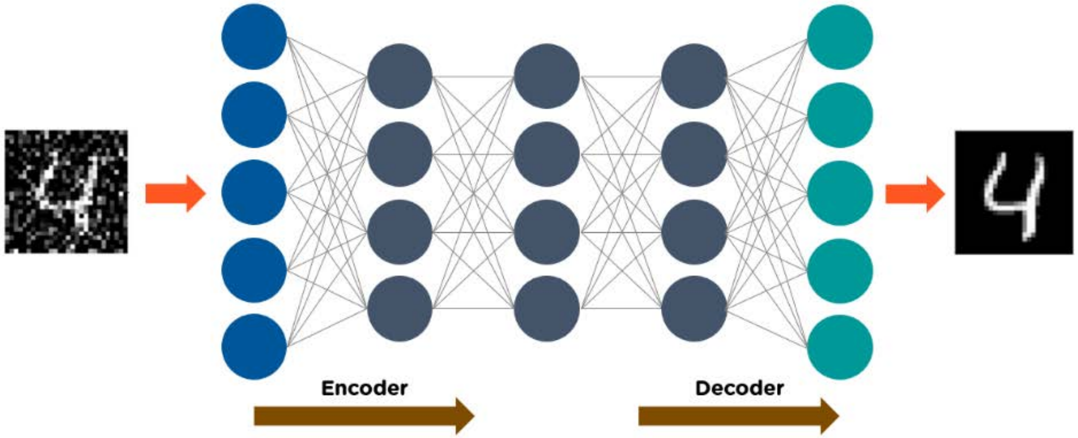
Generative Adversarial Networks (GANs)

- GANs are generative deep learning algorithms that create new data instances that resemble the training data. GAN has two components: a generator, which learns to generate fake data, and a discriminator, which learns from that false information.
- The usage of GANs has increased over a period of time. They can be used to improve astronomical images and simulate gravitational lensing for dark-matter research. Video game developers use GANs to upscale low-resolution, 2D textures in old video games by recreating them in 4K or higher resolutions via image training.
- GANs help generate realistic images and cartoon characters, create photographs of human faces, and render 3D objects.
- How Do GANs work?
  - The discriminator learns to distinguish between the generator's fake data and the real sample data.
  - During the initial training, the generator produces fake data, and the discriminator quickly learns to tell that it's false.
  - The GAN sends the results to the generator and the discriminator to update the model.



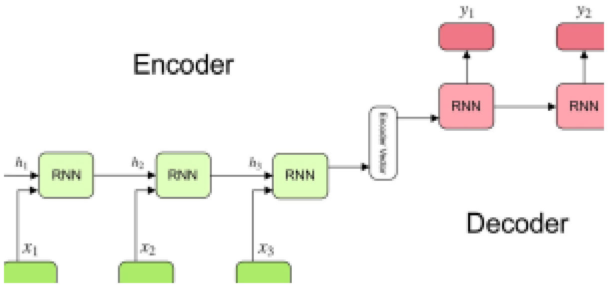
Auto-Encoder

- Autoencoders are a specific type of feedforward neural network in which the input and output are identical. Geoffrey Hinton designed autoencoders in the 1980s to solve unsupervised learning problems. They are trained neural networks that replicate the data from the input layer to the output layer. Autoencoders are used for purposes such as pharmaceutical discovery, popularity prediction, and image processing.
- How Do Autoencoders Work?
  - An autoencoder consists of three main components: the encoder, the code, and the decoder.
  - Autoencoders are structured to receive an input and transform it into a different representation. They then attempt to reconstruct the original input as accurately as possible.
  - When an image of a digit is not clearly visible, it feeds to an autoencoder neural network.
- Autoencoders first encode the image, then reduce the size of the input into a smaller representation.
  - Finally, the autoencoder decodes the image to generate the reconstructed image.



Generative AI

- Generative AI is a cover term of deep learning frameworks that are aimed to *generate* outputs: texts, images, etc.



- Generative AI is realized with very large deep learning models in which the learned features are fully encoded, which enables to generate apparently new outputs

Deep Reinforcement Learning

- Reinforcement learning is another type of ML that has no answer labels (different from Supervised Learning) but has indirect information toward answers (different from Unsupervised Learning).

Reinforcement learning	Supervised learning
Reinforcement learning is all about making decisions sequentially. In simple words, we can say that the output depends on the state of the current input and the next input depends on the output of the previous input	In Supervised learning, the decision is made on the initial input or the input given at the start
In Reinforcement learning decision is dependent, So we give labels to sequences of dependent decisions	In supervised learning the decisions are independent of each other so labels are given to each decision.
Example: Chess game,text summarization	Example: Object recognition, spam detetction

- For more detailed introduction:
  - https://www.v7labs.com/blog/deep-reinforcement-learning-guide