ICTSS00120 - Artificial Intelligence Skill Set

Session 3: Essentials of ML and DL Technologies

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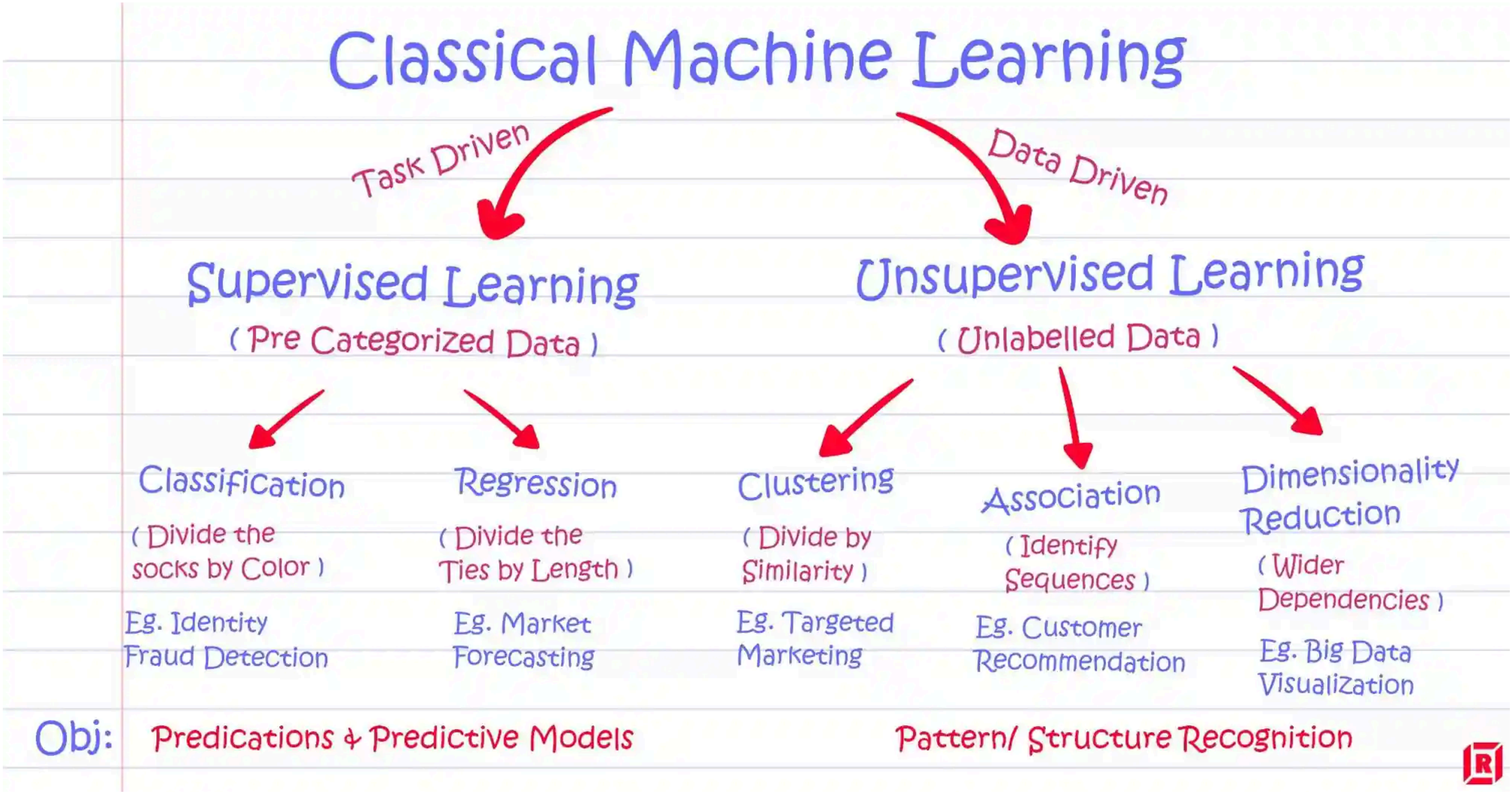
GOVERNMENT OF WESTERN AUSTRALIA
TAFE WA North Metropolitan

Learning Objectives

- Introduction to the sci-kit learn package.
- Understand supervised vs. unsupervised learning.
- Introduction to deep learning (DL) and its place within AI.
- Learn about regression and classification techniques.
- Explore clustering and dimensionality reduction techniques.
- Understand reinforcement learning.
- Introduction to various deep learning architectures.

Introduction to Sci-Kit Learn

- **What is Sci-Kit Learn?**
  - Open-source machine learning library for Python.
  - Built on NumPy, SciPy, and Matplotlib.
  - Provides simple and efficient tools for data mining and data analysis.
  - Accessible and reusable in various contexts.
- **Why Sci-Kit Learn?**
  - Rich set of machine learning algorithms.
  - Excellent documentation and community support.


Classical Machine Learning
Task Driven
Data Driven
Supervised Learning
(Pre Categorized Data)
Unsupervised Learning
(Unlabelled Data)
Classification
(Divide the socks by Color)
Eg. Identity Fraud Detection
Regression
(Divide the Ties by Length)
Eg. Market Forecasting
Clustering
(Divide by Similarity)
Eg. Targeted Marketing
Association
(Identify Sequences)
Eg. Customer Recommendation
Dimensionality Reduction
(Wider Dependencies)
Eg. Big Data Visualization
Obj:
Predications & Predictive Models
Pattern/ Structure Recognition

Supervised vs. Unsupervised Learning

Supervised Learning

- **Definition:** Models are trained using labeled data.
- **Goal:** Predict outcomes for new data (e.g., classification, regression).
- **Examples**

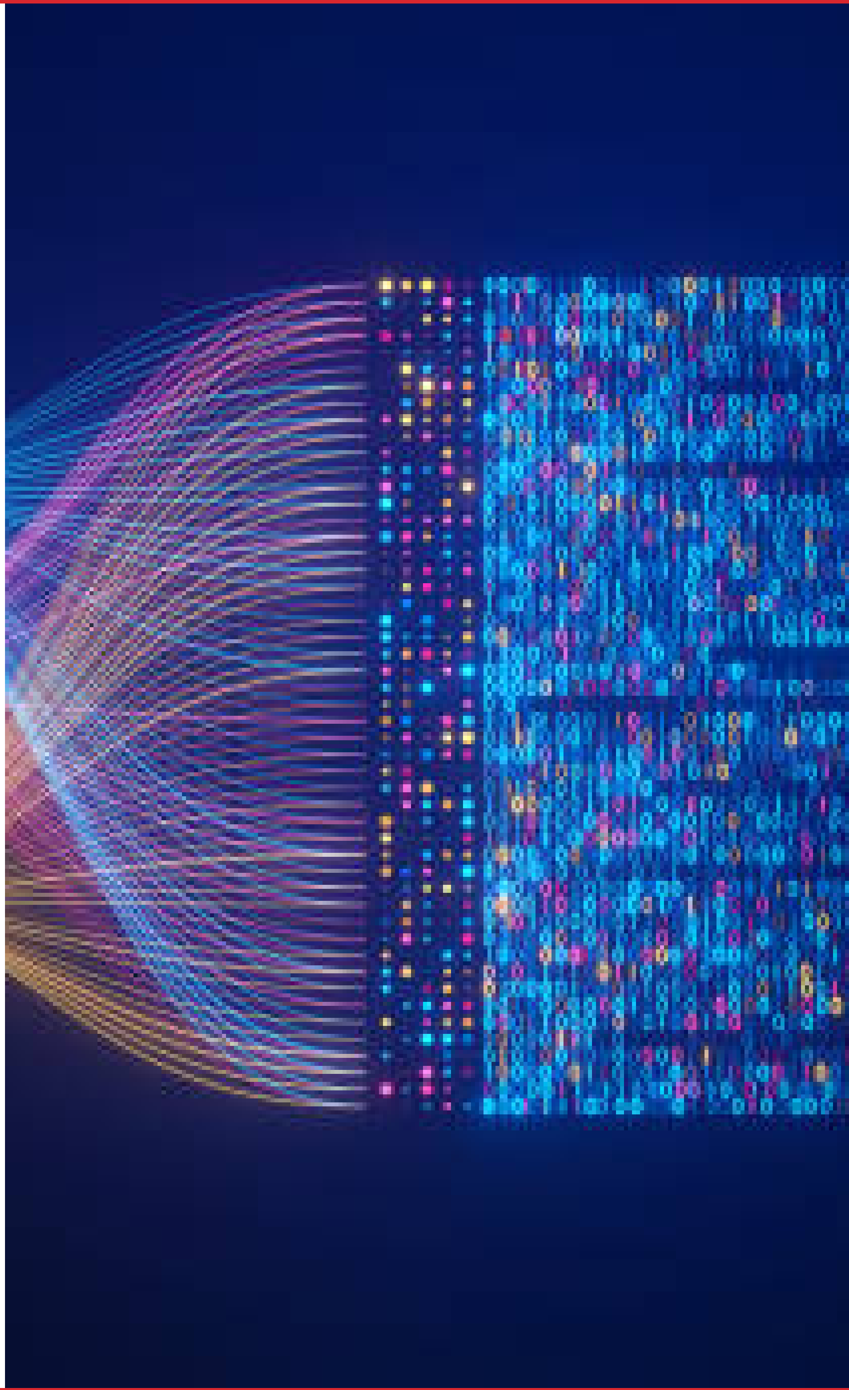
Unsupervised Learning

- **Definition:** Models are trained using unlabeled data.
- **Goal:** Discover hidden patterns or intrinsic structures.
- **Examples**

Introduction to Deep Learning (DL)

- **What is Deep Learning?**
  - Subset of ML involving neural networks with multiple (hidden) layers.
  - Capable of learning from vast amounts of data.
- **Place within AI:**
  - Enables more complex and abstract representations.
  - Powers advancements in computer vision, speech recognition, NLP, etc.

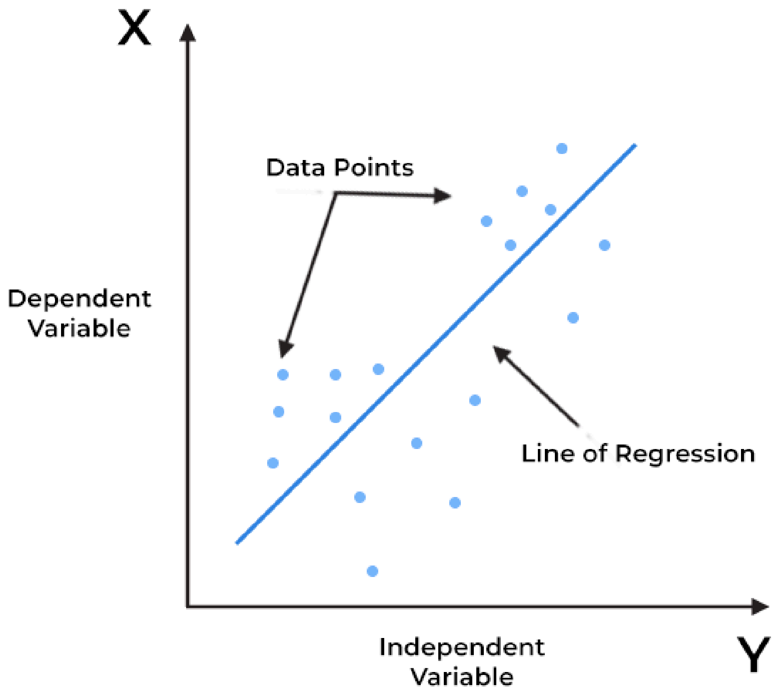
Key Tools: TensorFlow, PyTorch, Keras.



Regression & Classification - Supervised Learning

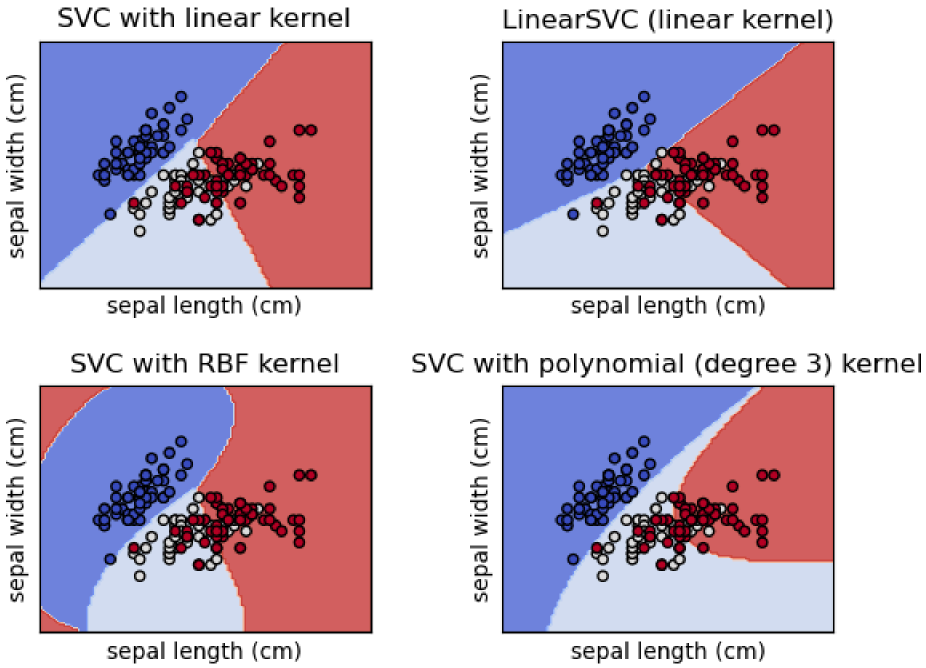
Linear Regression

- **Definition:** Linear approach to modeling the relationship between a dependent variable and one or more independent variables.
- **Application:** Predicting numerical values.



Support Vector Machines (SVM)

- **Definition:** Supervised algorithm that separates classes with a hyperplane.
- **Application:** Classifying data into categories.



Clustering & Dimensionality - Unsupervised Learning

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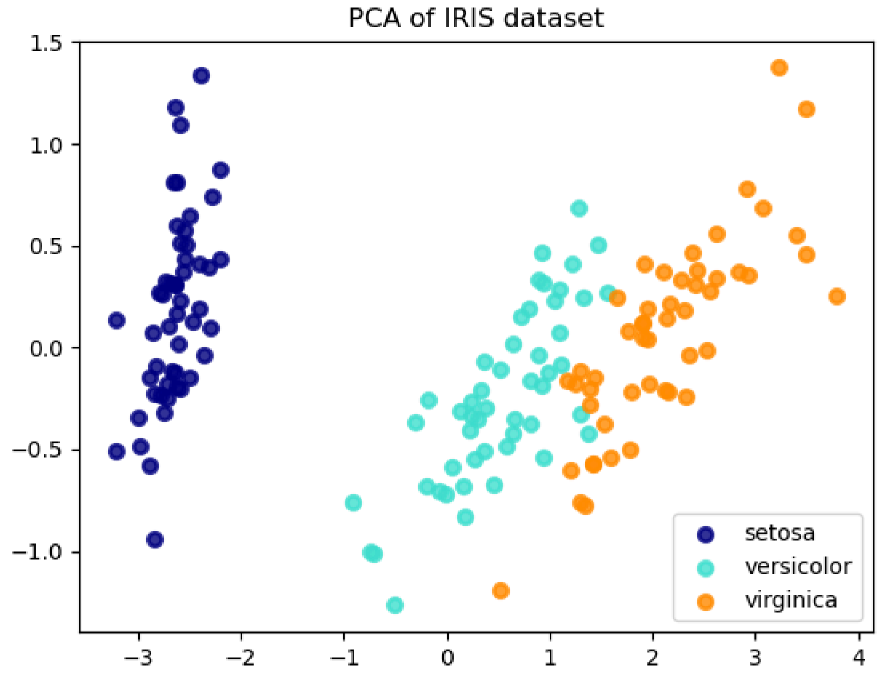
Principal Component Analysis (PCA)

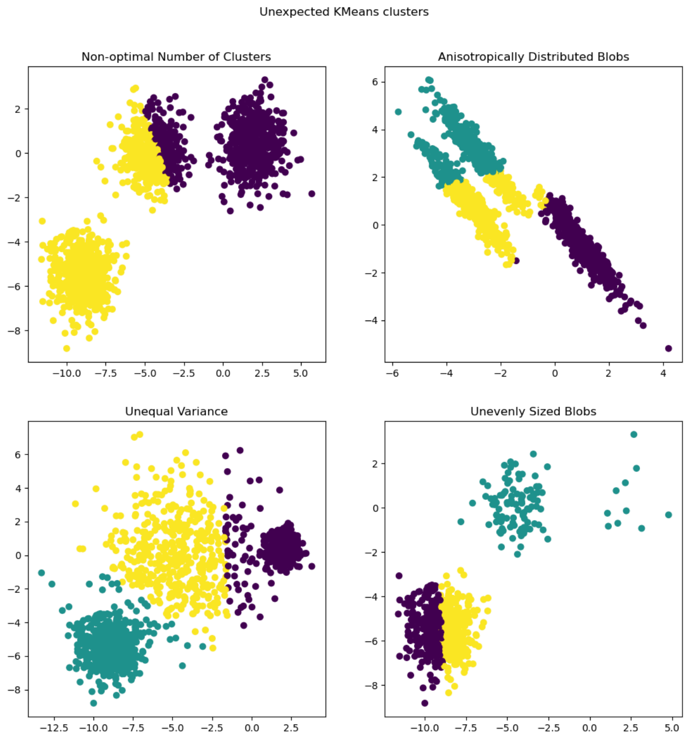
- **Definition:** Dimensionality reduction technique transforming data to a new coordinate system.
- **Application:** Reducing the number of features in datasets.



K-Means Clustering

- **Definition:** Partitions data into K clusters where each data point belongs to the cluster with the nearest mean.
- **Application:** Customer segmentation, market research.

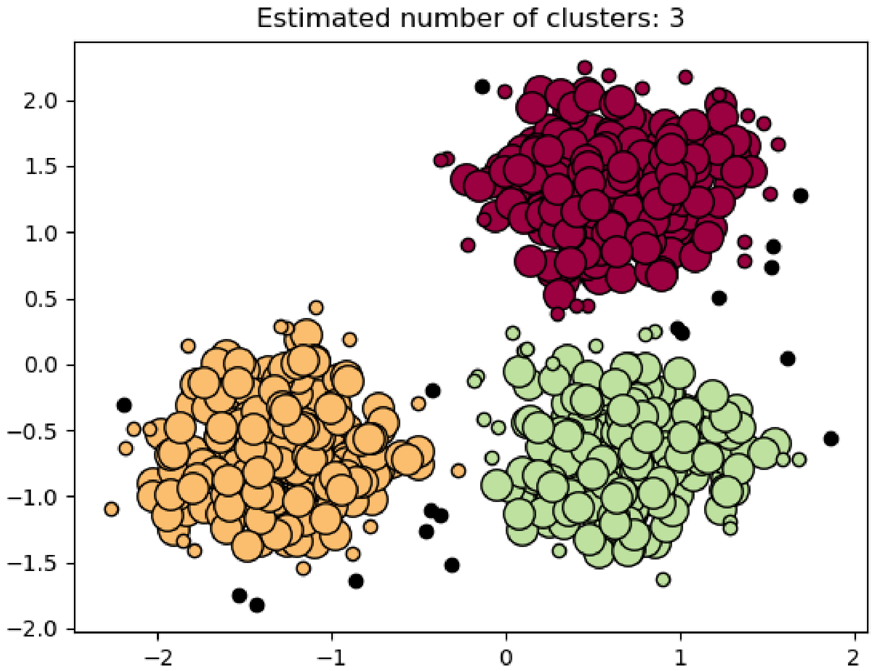
$$\sum_{i=0}^{n} \min_{\mu_j \in C}(||x_i - \mu_j||^2)$$



Sci-kit learn Article

DBSCAN (Density-Based Spatial Clustering of Applications with Noise)

- **Definition:** Clustering algorithm that groups points closely packed together while marking outliers.
- **Application:** Identifying clusters of varying shapes and densities.



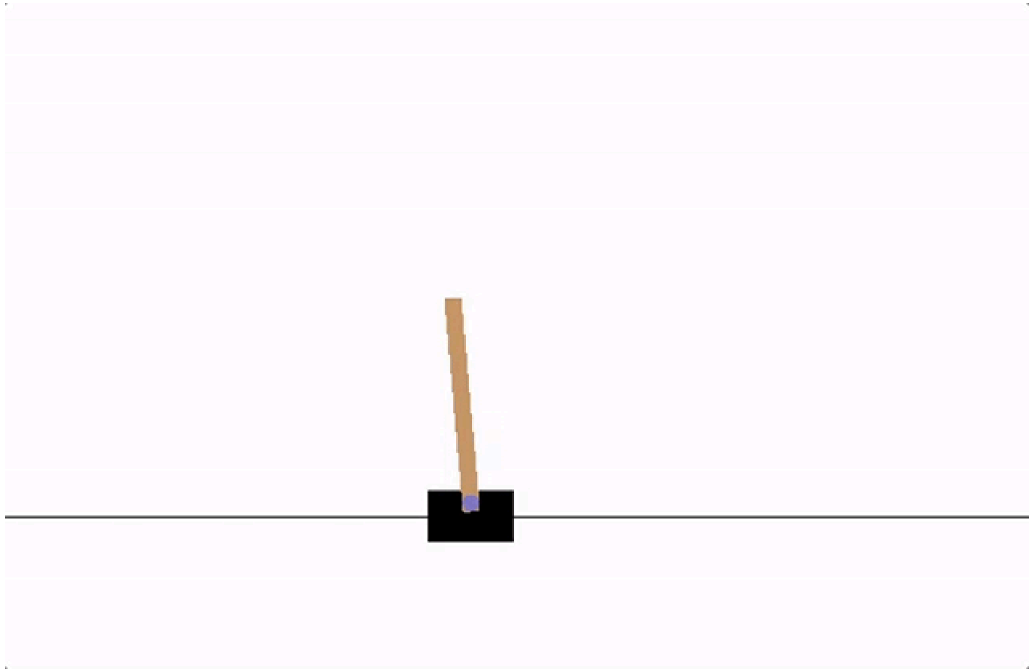
Other machine learning paradigms

Reinforcement Learning (RL)

- **Definition:** Learning paradigm where an agent learns by interacting with its environment to maximize cumulative reward.
- **Application:** Game playing, robotics, autonomous driving.

Not Supported by SciKit-Learn!!

Requires frameworks such as tensorflow, keras, or pytorch to manage more complex neural network architecture



Reinforcement learning is often thought of as a separate pillar of machine learning. Not quite supervised learning, not quite unsupervised.

It has a huge problem of alignment, however.

There is always some kind of proxy between the system/reward and the environment.

Rewards are often set arbitrarily and can be hard to do so without unforeseen consequences.

Semi-supervised learning

Overview

Semi-supervised learning is a machine learning technique that leverages both labeled and unlabeled data to build better models.

- Falls between supervised learning, which uses only labeled data, and unsupervised learning, which uses only unlabeled data.
- The driving idea behind semi-supervised learning is that the unlabeled data can provide useful information about the structure of the data distribution, thereby enhancing the learning process.

Approaches in Semi-Supervised Learning

1. **Self-training**:

- Initially train a model using the labeled data.
- Use this model to predict labels for the unlabeled data.
- Add the most confident predictions to the labeled dataset.
- Retrain the model using this augmented labeled dataset and repeat as needed.

2. **Co-training**:

- Train two models on different views (subsets of features) of the data.
- Each model uses the other's predictions on the unlabeled data to add confident examples to the labeled dataset.

3. **Graph-based Methods**:

- Treat the dataset as a graph, where nodes represent data points and edges represent similarities between them.
- Use techniques like label propagation to spread the label information from labeled to unlabeled points based on the graph structure.

4. **Generative Models**:

- Learn the distribution of the data and generate new data points. Use methods such as Variational Autoencoders (VAEs) or Generative Adversarial Networks (GANs) to enhance the learning process.

Practical Implementation Example Using Python and Scikit-learn

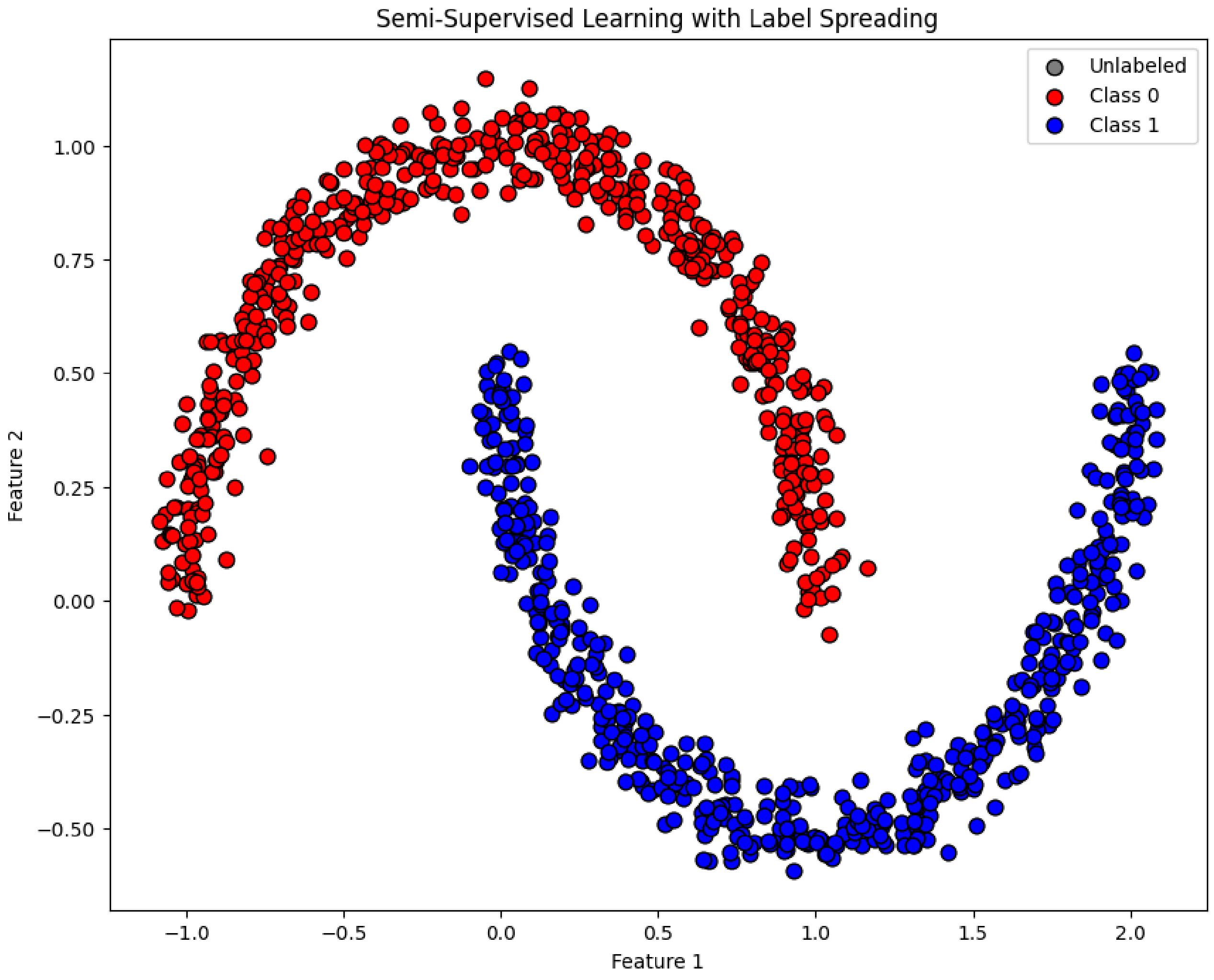
Let's look at a simple example of semi-supervised learning using the LabelSpreading algorithm from Scikit-learn

First import our dependencies:

```
import numpy as np
from sklearn import datasets
from sklearn.semi_supervised import LabelSpreading
import matplotlib.pyplot as plt
```

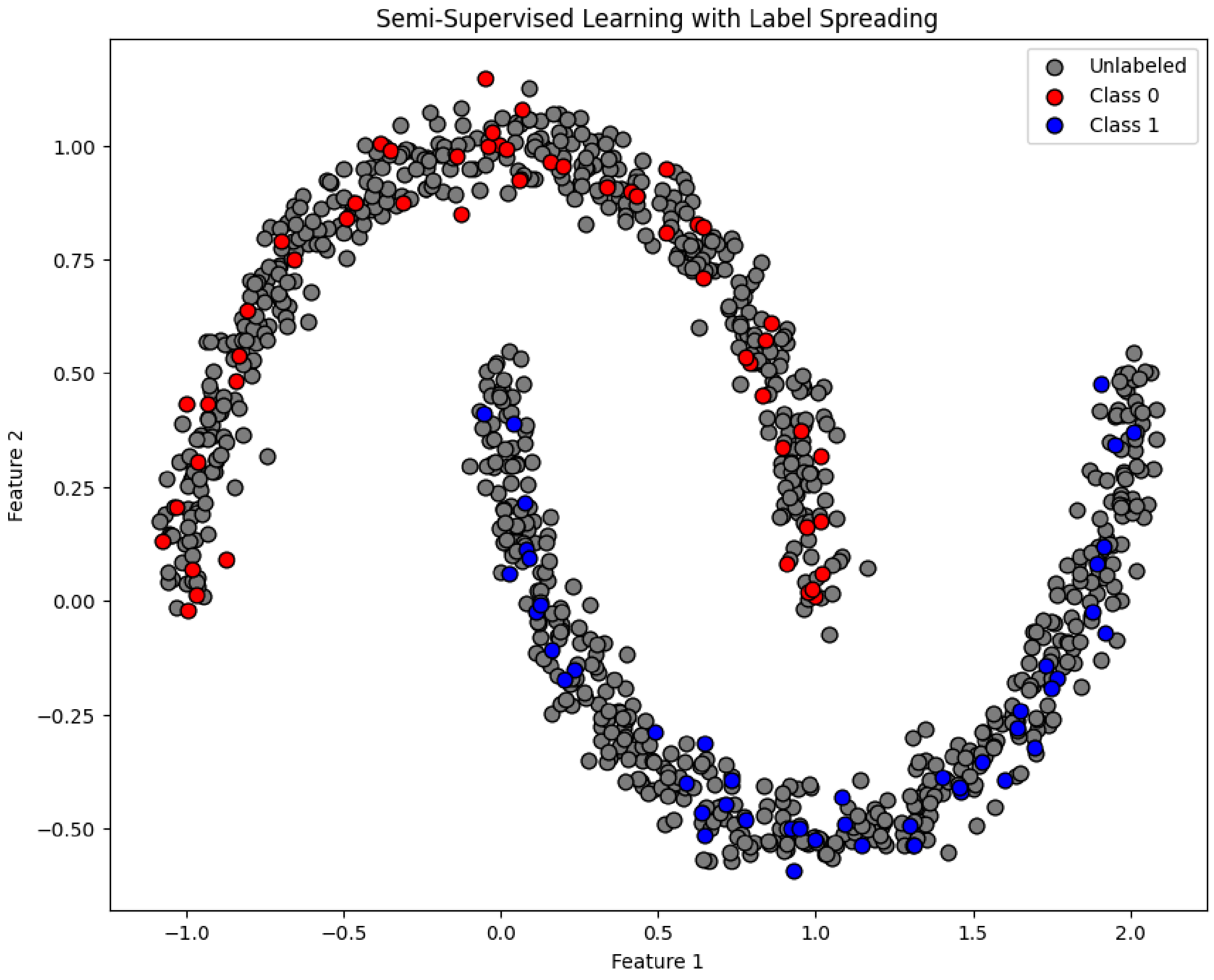
Next, we'll generate a synthetic dataset to work with

```
# Create a synthetic dataset
X, y = datasets.make_moons(n_samples=300, noise=0.1)
```



Let's unlabel most of the data to simulate a large amount of unlabeled data with some small set of labels

```
y[50:] = -1    # Unlabel majority of the data
```



Lets train our model

```
# Create and fit the model
label_spread = LabelSpreading(kernel='knn', alpha=0.8)
label_spread.fit(X, y)

# Predict labels for the entire dataset
y_pred = label_spread.transduction_
```

User guide in Sci-kit

alpha : *float, default=0.2*

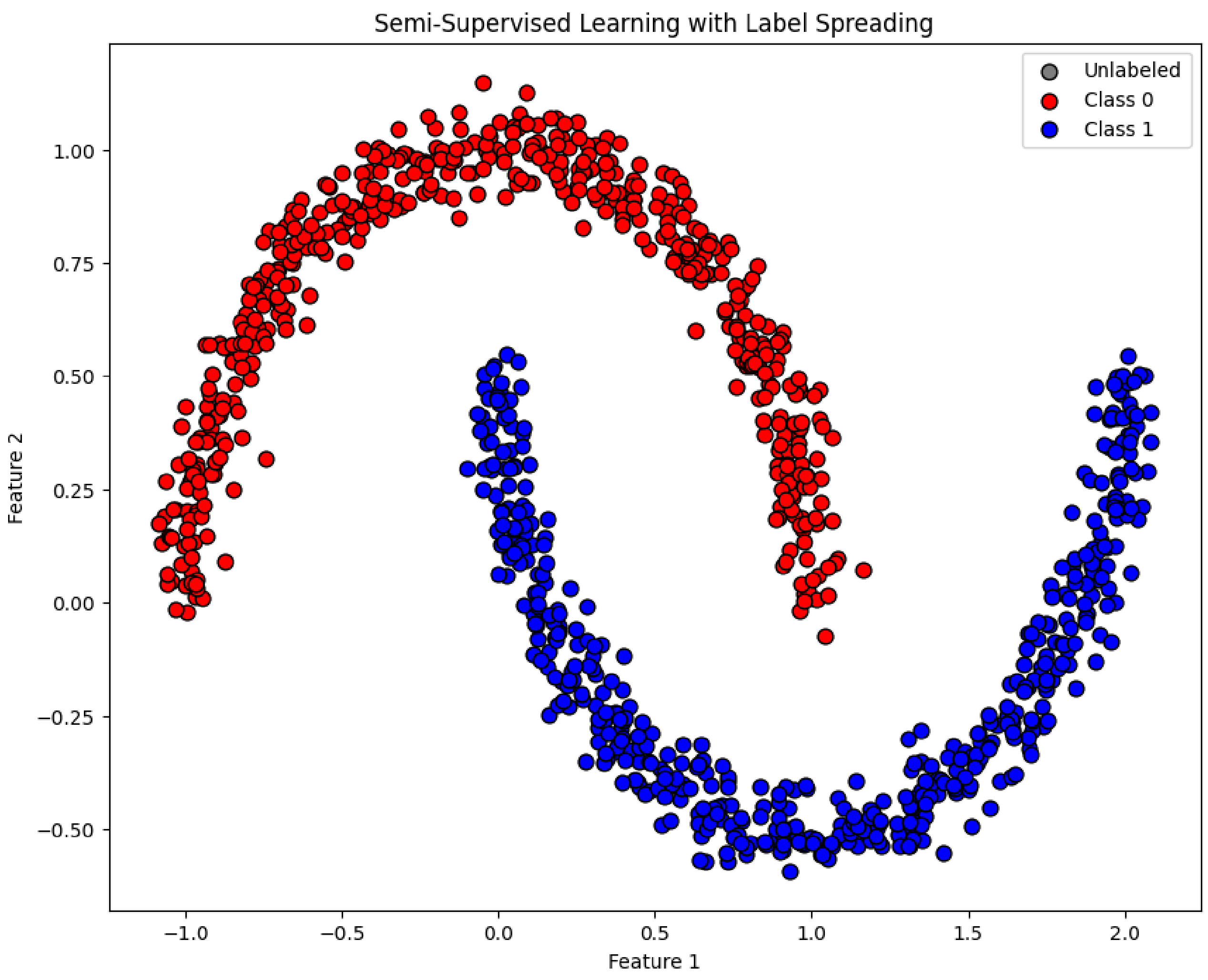
Clamping factor. A value in (0, 1) that specifies the relative amount that an instance should adopt the information from its neighbors as opposed to its initial label. alpha=0 means keeping the initial label information; alpha=1 means replacing all initial information.

Results??

```
# Plot the results
plt.figure(figsize=(8, 5))
cm = plt.cm.RdBu
plt.scatter(X[:, 0], X[:, 1], c=y_pred, cmap=cm, edgecolors='k')
plt.title("Semi-Supervised Learning with Label Spreading")
plt.show()
```

Yay! we re-labeled our data

Now we can train our model using the whole dataset rather than the 10% that was labeled initially

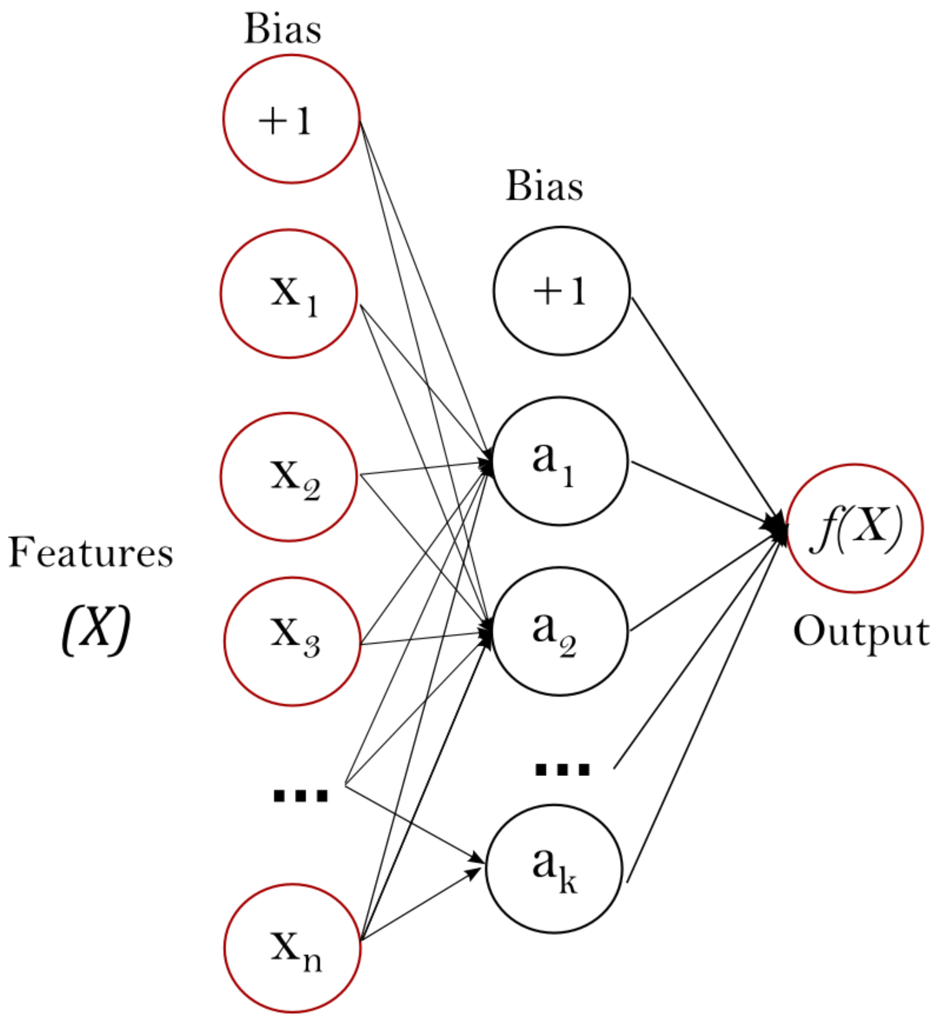


Deep Learning Architectures

Feed Forward Neural Networks (FNN/MLP)

- **Definition:** Simplest type of artificial neural network with information flowing only forward.
- **Application:** Basic pattern recognition.

SciKit-Learn Article



Recurrent Neural Networks (RNN) (pytorch etc..)

- **Definition:** Networks where connections form directed cycles, allowing temporal dynamic behavior.
- **Application:** Sequence prediction, time series analysis.

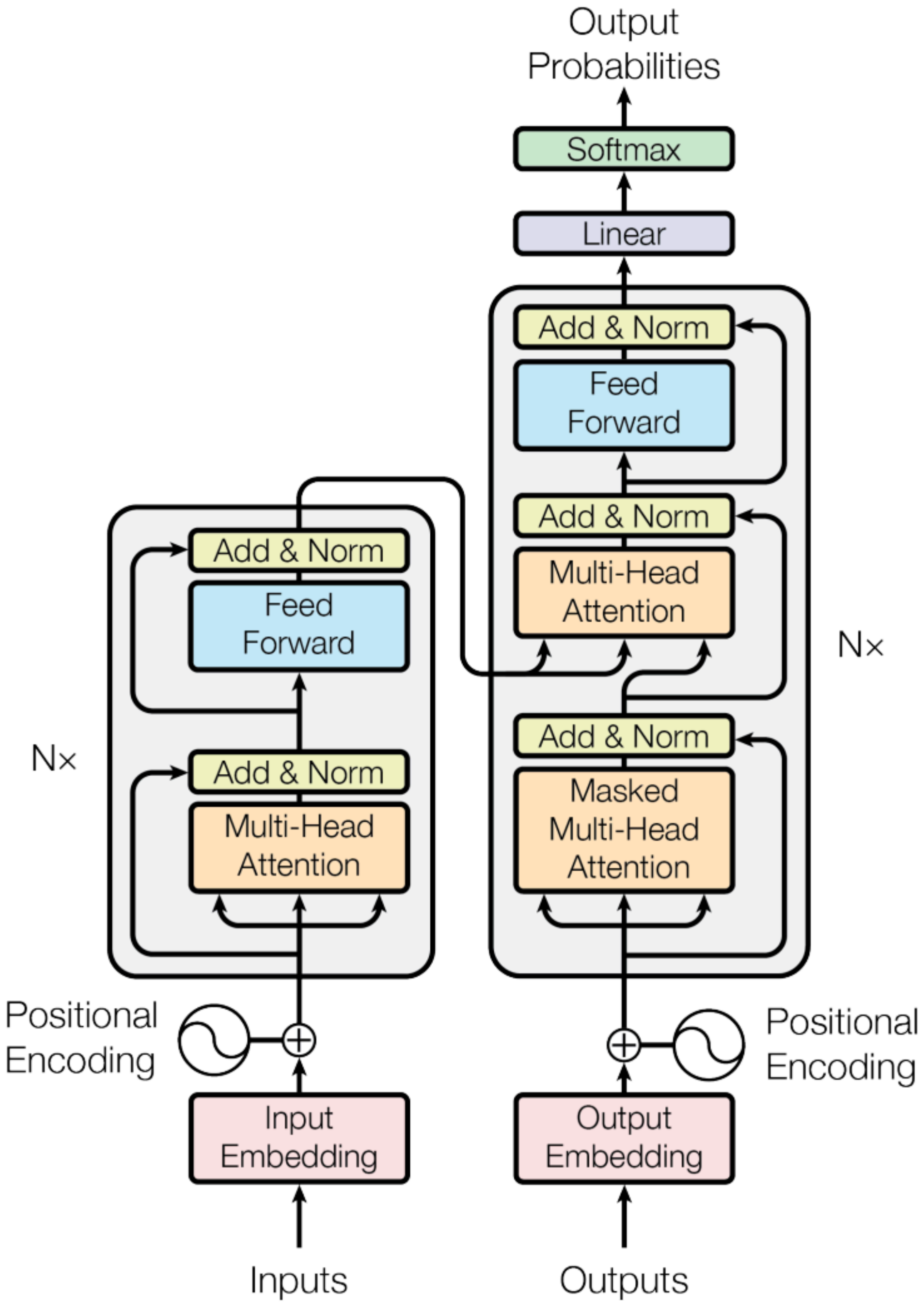
Great Article/Tutorial to read and try!

pytorch documentation RNN

🤖 Transformers 🤗

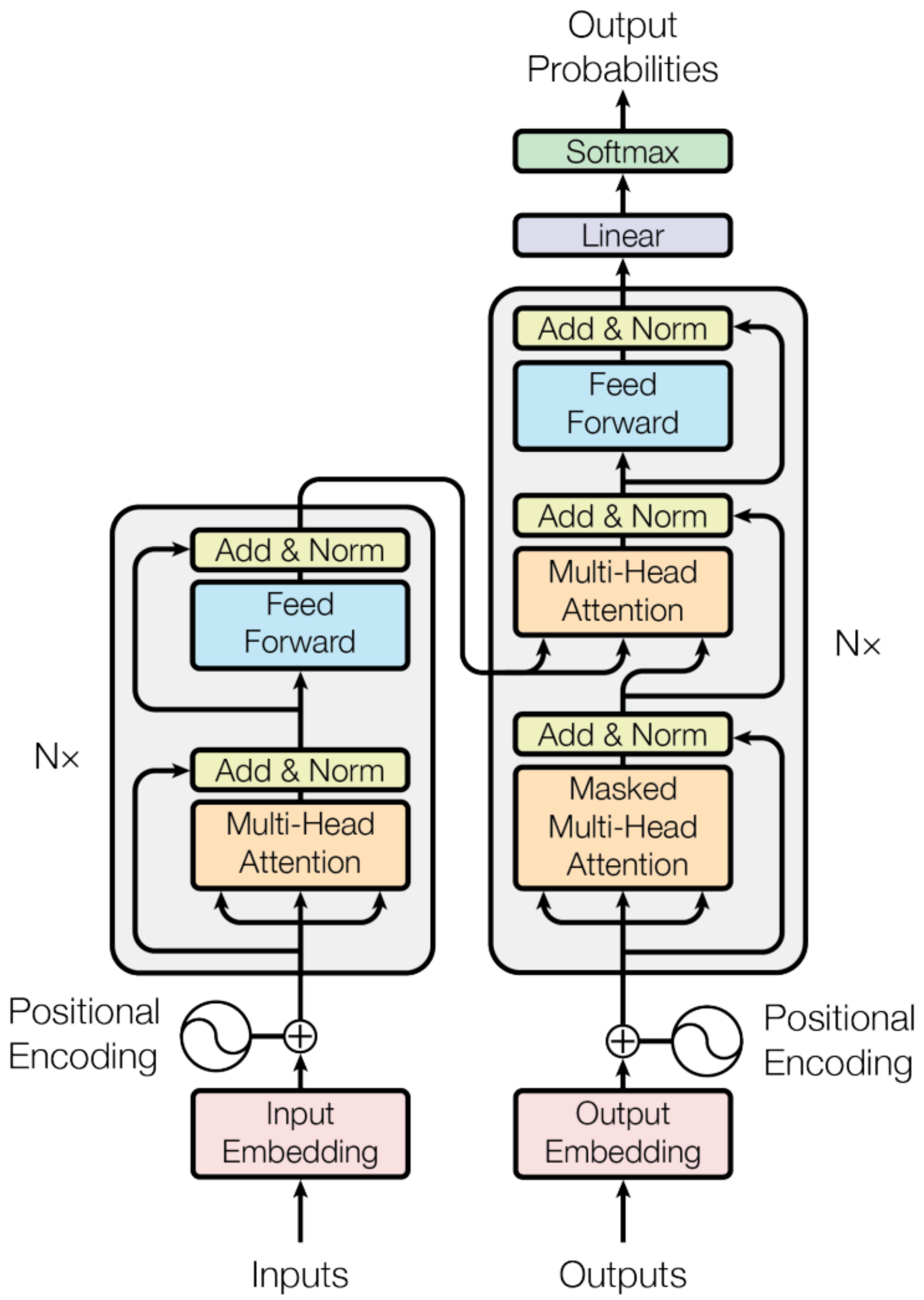
- **Definition:** Attention mechanism allowing the models to focus on different parts of the input sequence.
- **Application:** Natural Language Processing (NLP), such as BERT, GPT. (And much more...)

Transformer = Attention + FNN/MLP



BERT

Encoder



GPT

Decoder

Limitations of Sci-Kit Learn

- **Limited Deep Learning Support:**
  - Primarily focused on traditional ML algorithms.
  - For deep learning tasks, TensorFlow, PyTorch, or Keras recommended.
- **Scalability:**
  - Not optimized for very high-dimensional data or extremely large datasets.
- **Real-Time Model Serving:**
  - Not designed for real-time application deployment.
- **Feature Set:**
  - May lack certain cutting-edge algorithms found in specialized deep learning frameworks.

Summary

- Introduction to the sci-kit learn package.
- Differences between supervised and unsupervised learning.
- Basics of deep learning and its architectures.
- Overview of key ML techniques (regression, classification, clustering).
- Understand reinforcement learning and its applications.
- Limitations of the sci-kit learn package.

Key Takeaways

- **Sci-Kit Learn:** Robust library for traditional ML tasks.
- **Learning Types:** Importance of supervised and unsupervised learning.
- **Deep Learning:** Know the basics of different DL architectures.
- **Algorithms:** Understanding various techniques available in sci-kit learn.
- **Limitations:** Knowing when to use other frameworks for deep learning tasks.

In-Class Activity/Workshop: Applying Sci-Kit Learn

Activity Overview

- **Objective:** Apply various machine learning techniques using the sci-kit learn package to a sample dataset.
- **Lab Sheet:** Markdown Lab Sheet

Discussion:

- Discuss the results with peers.
- Reflect on the performance of different techniques.
- Identify potential biases or issues in the dataset and model.

Questions & Answers

Q&A

- Questions from today's session??

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Next Week

Data Bias and Ethics in AI

Next Week's topics:

- Implementation Risks
- Ethics in AI, including Australia’s AI Ethics Framework
- Alignment

Home Work!

Before class next week read:

Australia's AI Ethics Principles

"I Have No Mouth, and I Must Scream" by Harlan Ellison

"Robbie" by Isaac Asimov

We will be discussing these texts next week in-class

Choose one of the readings from the last 3 weeks:

Come to class with a question for the class about one of the assigned readings.

You will be asked to provide your question to the class tomorrow for discussion.

Think: How well does the AI Ethics Principles address issues raised in our readings?