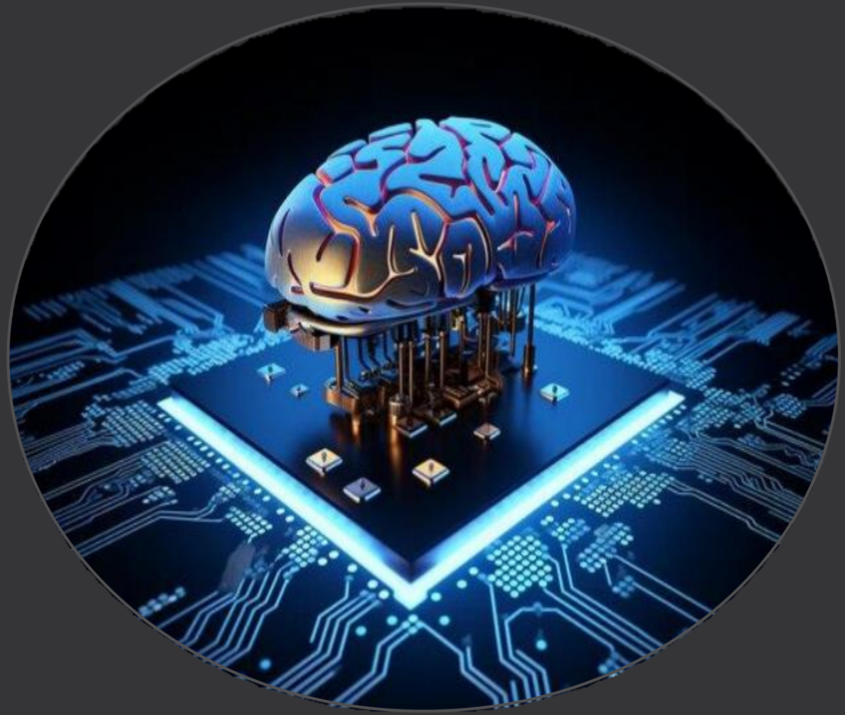
Machine Learning

From Inception to Innovation



Overview

- Introduction to Machine Learning
- Historical Background
- Evolution of Machine Learning
- Types of Machine Learning
- Key Concepts
- Common Algorithms
- Data Preprocessing
- Model Training and Evaluation
- Tools and Frameworks
- Real-world Applications
- Challenges and Limitations
- Future Trends
- References

Introduction To Machine Learning

Definition

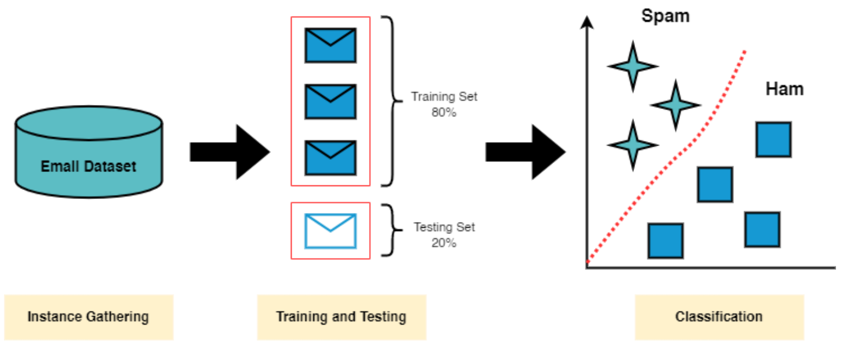
- Machine learning is the science (and art) of programming computers so they can learn from data.

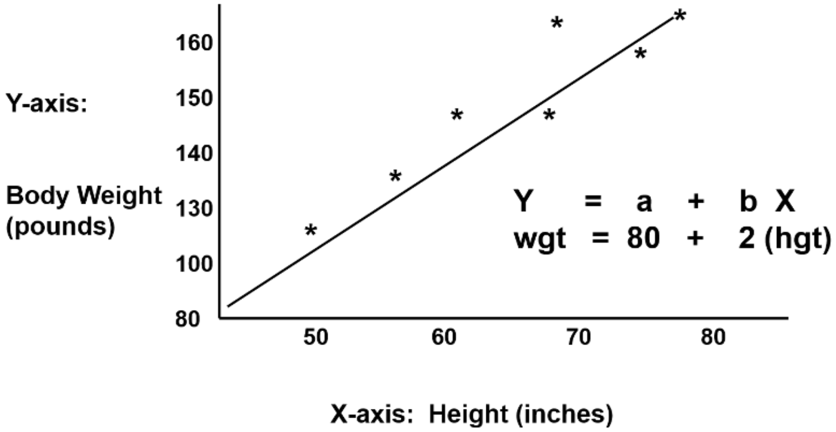
- [Machine learning is the] field of study that gives computers the ability to learn without being explicitly programmed.

— Arthur Samuel, 1959

- A computer program is said to learn from experience E with respect to some task T and some performance measure P, if its performance on T, as measured by P, improves with experience E.

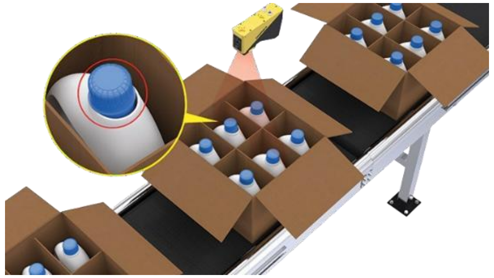
—Tom Mitchell, 1997

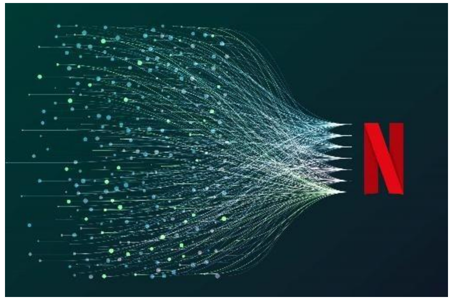




Introduction To Machine Learning cont..

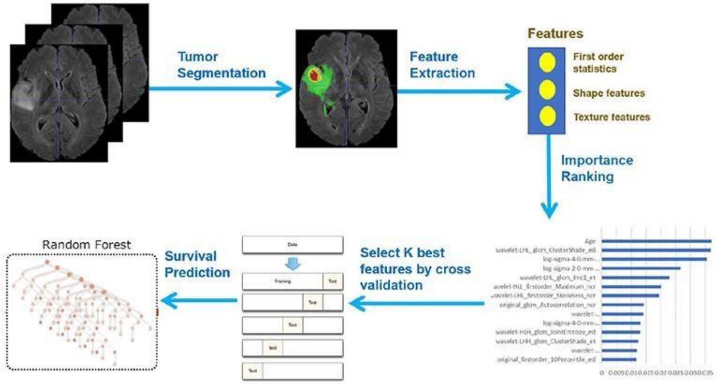
Importance in the Modern World

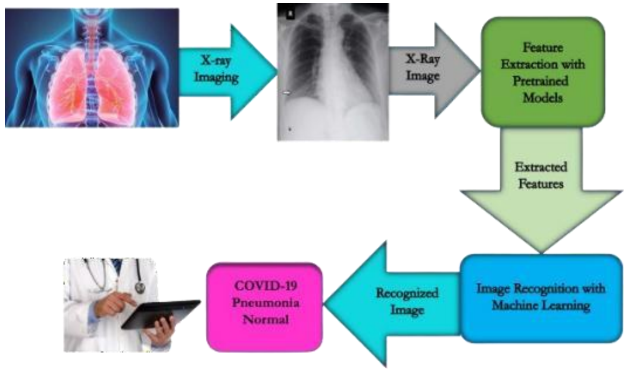




Machine Learning is crucial in today's world for several reasons:

- Analyzing images of products on a production line to automatically classify them
- Detecting tumors in brain scans
- Summarizing long documents automatically

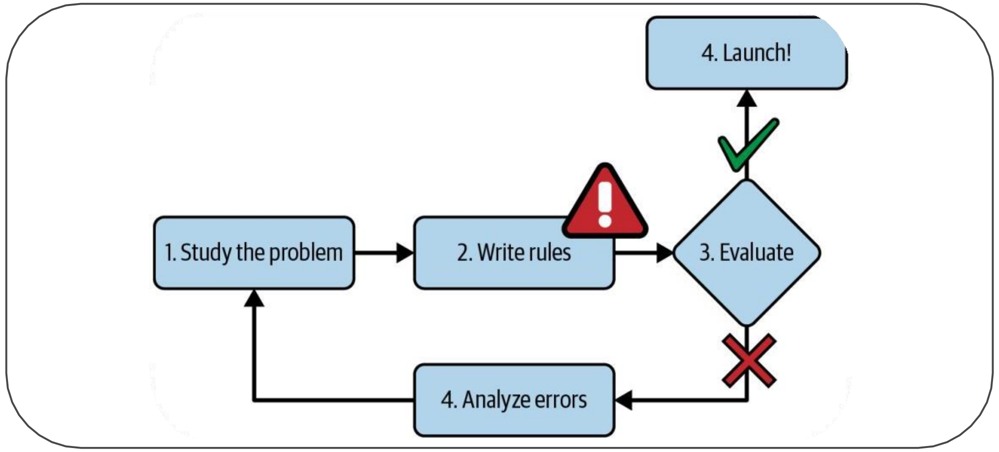




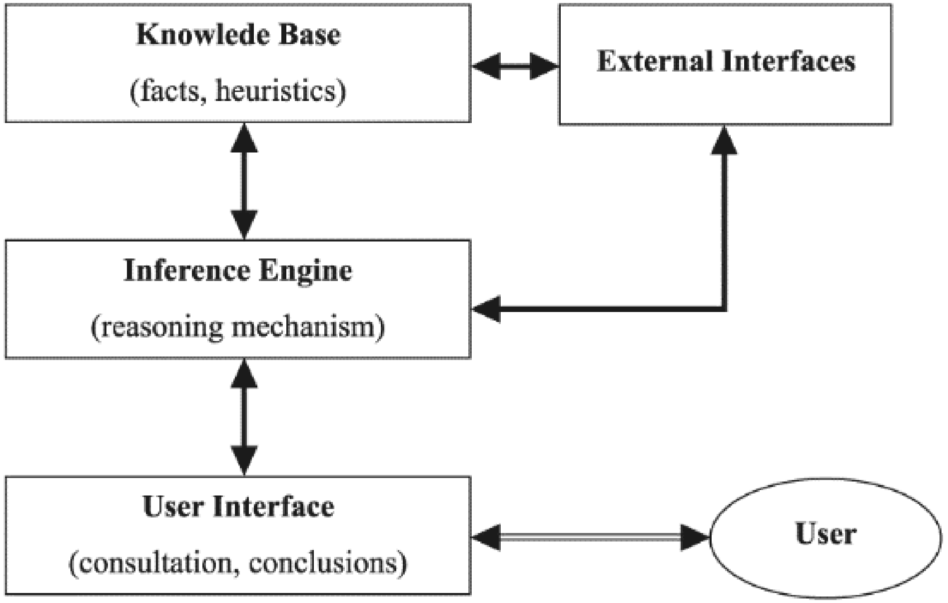
Historical Background

Early Methods Before Machine Learning

- **Rule-Based Systems**
  - MYCIN (used for diagnosing bacterial infections)



- **Expert Systems**
  - DENDRAL, an early expert system, developed beginning in 1965 by the artificial intelligence (AI) researcher Edward Feigenbaum and the geneticist Joshua Lederberg, both of Stanford University in California.
  - DENDRAL, an expert system for chemical analysis, inferred molecular structures from spectroscopic data.

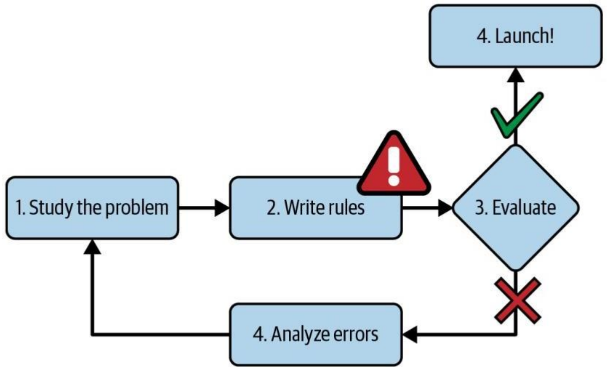


- **Traditional Statistical Methods**
  - Linear regression, used for finding and explaining relationship between variables based on historical data patterns.

Historical Background cont…

Limitations of Pre-ML Methods

- **Scalability**
  - Manual rule creation and maintenance
- **Flexibility**
  - Non-linear relationships and complex data patterns
- **Adaptability**
  - Required extensive human intervention to update rules or adapt to new data trends, limiting real-time decision-making capabilities.
- **Generalization**
  - Expert systems were often domain-specific



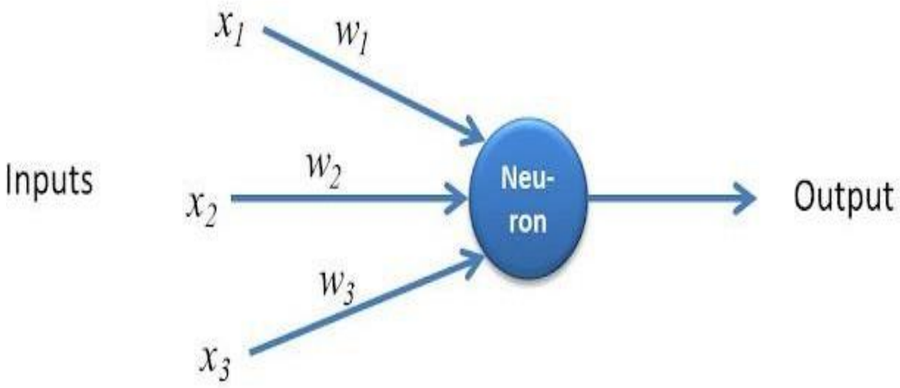
Evolution of Machine Learning

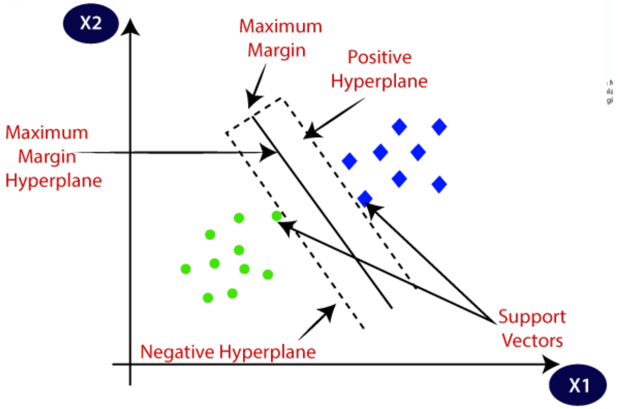
Early Developments

- **Dartmouth Conference (1956)**
  - The Dartmouth Conference, held in 1956, is considered the birthplace of Artificial Intelligence (AI) as a field.
  - Researchers gathered to discuss the potential of creating intelligent machines.
- **Initial Algorithms and Theories**
  - Perceptron (1957) - Frank Rosenblatt
  - Decision Trees (1960s) - ID3
  - Bayesian Networks (1980s) - probabilistic models

Key Milestones

- **Development of Neural Networks**
  - Backpropagation (1986) - Rumelhart, Hinton, and Williams
  - Support Vector Machines (1990s) - Vapnik and Cortes

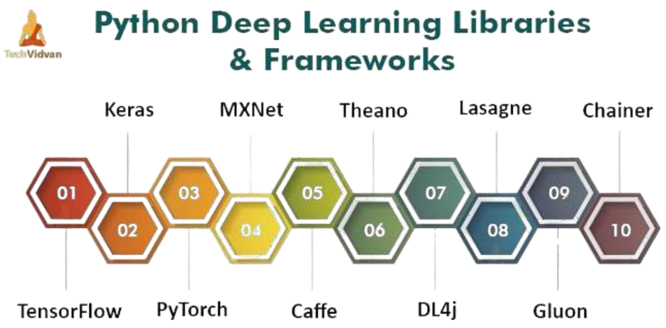




Evolution of Machine Learning cont…

Rise of Big Data and Computational Power

- **Big Data (2000s)**
  - Internet, sensors, and various digital platforms provided vast amounts of information for training ML models.
- **Improved Hardware**
  - Advances in computational power, particularly with GPUs
- **Frameworks and Libraries**
  - TensorFlow, PyTorch, and scikit-learn



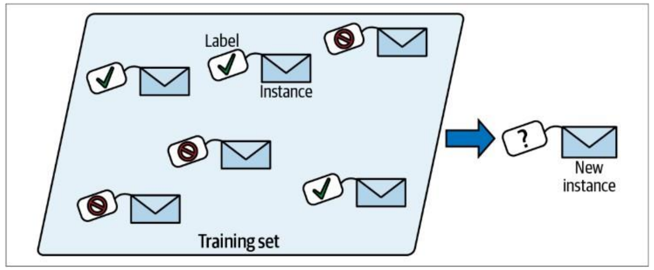
Emergence of Deep Learning

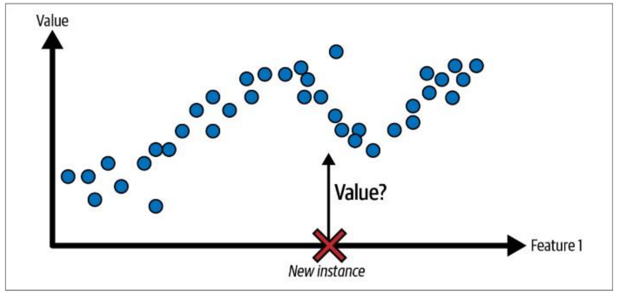
- **Deep Learning (2010s)**
  - Convolutional Neural Networks (CNNs)
  - Recurrent Neural Networks (RNNs)
- **AlphaGo (2016)**
  - Google's DeepMind
- **GPT Models (2018-2021s)**
  - OpenAI

Types of Machine Learning

Supervised Learning

- **Definition**
  - Supervised Learning involves training a model on a labeled dataset, where the input data is paired with the correct output.
  - The model learns to map inputs to outputs based on this labeled data.
- **Example**
  - **Regression:** Predicting a continuous value. For example, predicting house prices based on features like size, location, and age.
  - **Classification:** Categorizing input data into predefined classes. For example, identifying whether an email is spam or not spam based on its content.

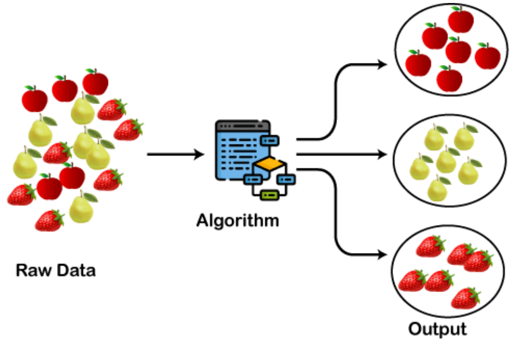




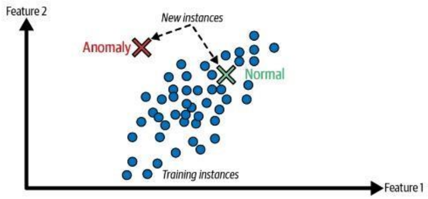
Types of Machine Learning cont…

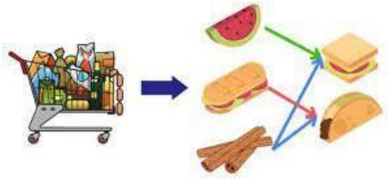
Unsupervised Learning

- **Definition:**
  - Unsupervised Learning involves training a model on data that does not have labeled responses.
  - The model tries to find hidden patterns or intrinsic structures in the input data.



- **Example**
  - **Clustering:** Grouping similar data points together. For example, customer segmentation in marketing, where customers are grouped based on purchasing behavior.
  - **Anomaly Detection:** Identifying outliers or unusual data points that do not conform to the expected pattern. For example, detecting fraudulent transactions in financial systems.
  - **Association:** Discovering rules that describe large portions of the data. For example, market basket analysis in retail, where associations between products bought together are identified.

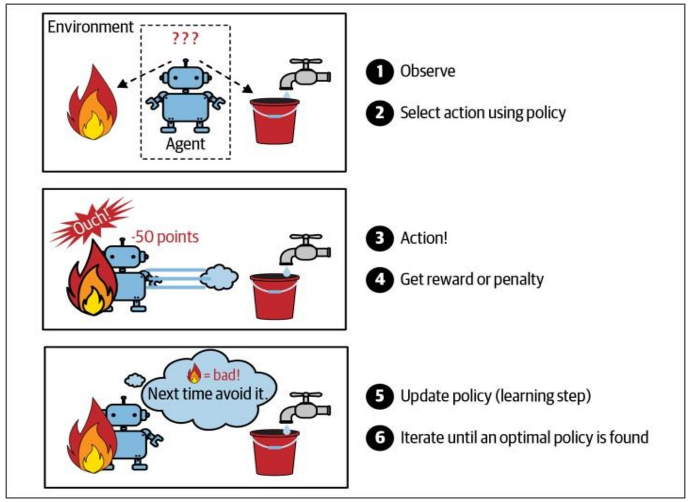


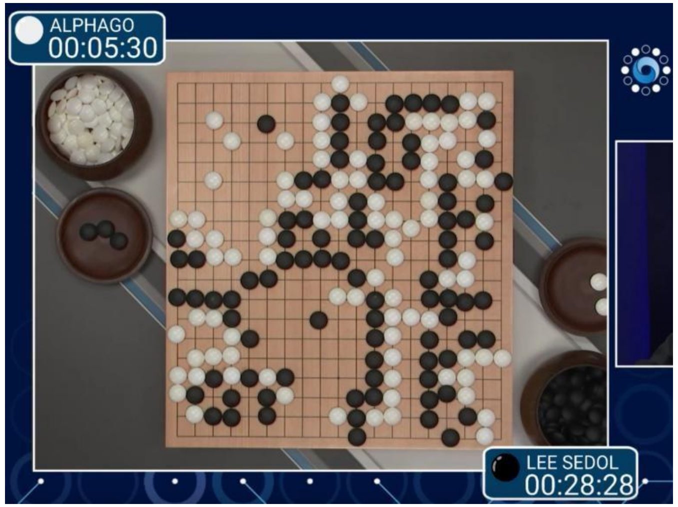


Types of Machine Learning cont…

Reinforcement Learning

- **Definition**
  - Reinforcement Learning involves training a model to make sequences of decisions by interacting with an environment.
  - The model receives feedback in the form of rewards or penalties and learns to optimize its actions to maximize cumulative rewards.
- **Example**
  - **Game Playing:** Training an AI to play games like Chess or Go, where the AI learns strategies through trial and error and feedback from wins or losses.
  - **Robotics:** Teaching a robot to navigate and perform tasks in an environment, such as a robot learning to walk or pick up objects, by receiving feedback from its actions.





Key Concepts

Data and Features

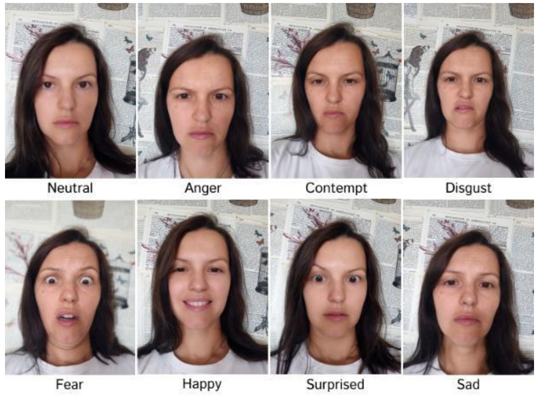
- **Data**
  - The raw information collected from various sources, such as text, images, or numerical values, that is used to train machine learning models.
  - **Example:** A dataset of housing prices with columns like size, number of bedrooms, location, and price.
- **Features**
  - The individual measurable properties or characteristics of the data that are used as input for the model.
  - **Example:** In the housing dataset, features would include size, number of bedrooms, and location.

Columns

Rows

Values

ID	Outlook	Temp	Humidity	Windy	Play Golf
1	Rainy	85	92	False	No
2	Rainy	80	88	True	No
3	Overcast	83	86	False	Yes
4	Sunny	70	80	False	Yes
5	Sunny	68	?	False	Yes
6	Sunny	65	58	True	No
7	Overcast	64	62	True	Yes
8	Rainy	72	95	?	No
9	Rainy	?	70	False	Yes
10	Sunny	75	72	False	Yes
11	Rainy	75	74	True	Yes
12	?	72	78	True	Yes
13	Overcast	81	66	False	Yes
14	Sunny	71	79	True	No

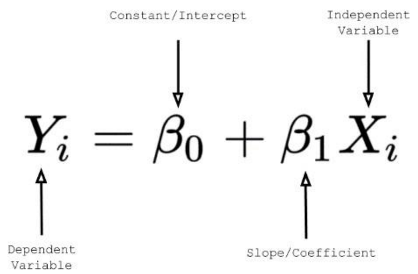


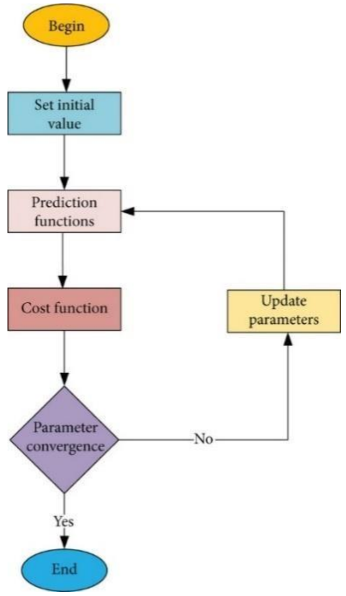
Key Concepts cont…

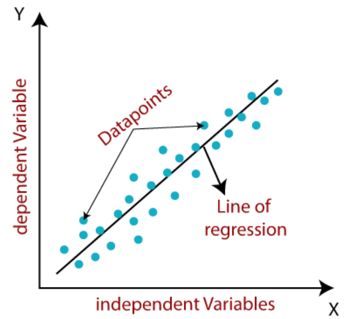
Algorithms and Models

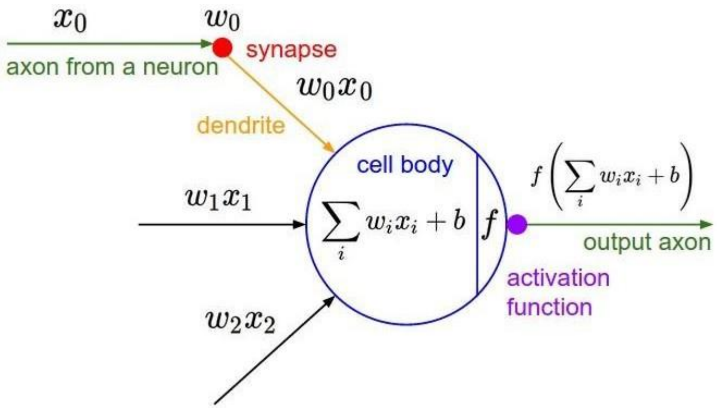
- **Algorithms**
  - The step-by-step procedures or formulas used to perform calculations and process data.
  - In machine learning, algorithms are used to train models.
  - **Example**: Linear Regression, Logistic Regression, neural networks etc.

- **Model**
  - The output of a machine learning algorithm that has been trained on data.
  - Models make predictions or decisions based on new data.
  - **Example:** A trained model that can predict house prices based on size, number of bedrooms, and location.





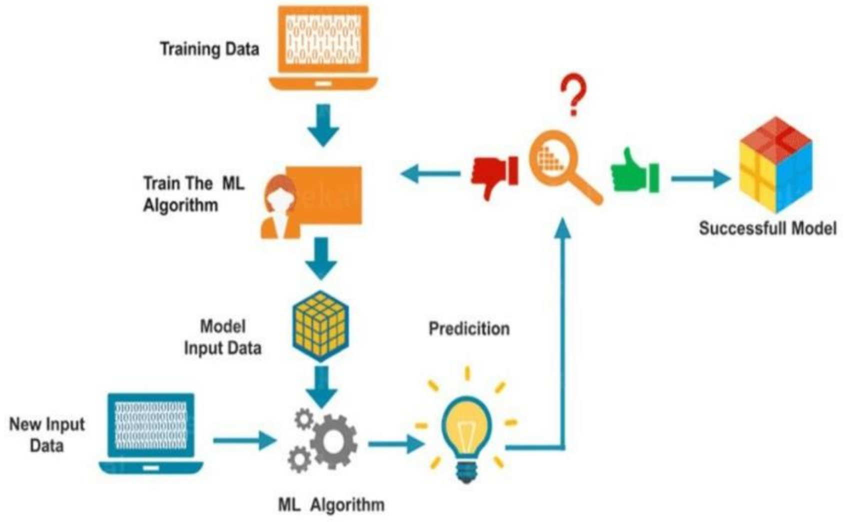


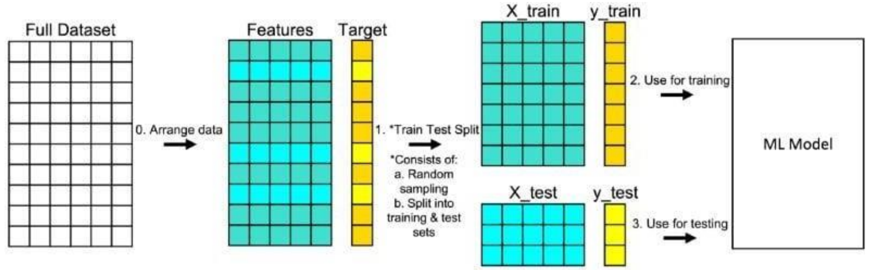


Key Concepts cont…

Training and Testing

- **Training**
  - The process of teaching a machine learning model using a dataset.
  - The model learns patterns and relationships from the training data.
- **Testing**
  - The process of evaluating the trained model on a separate dataset to assess its performance.
  - This helps ensure that the model generalizes well to new, unseen data.



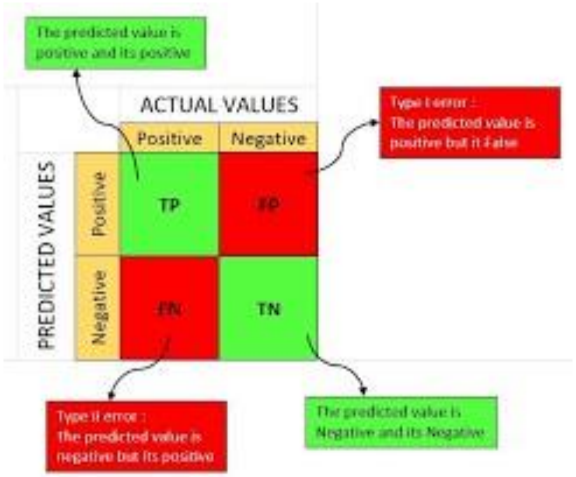


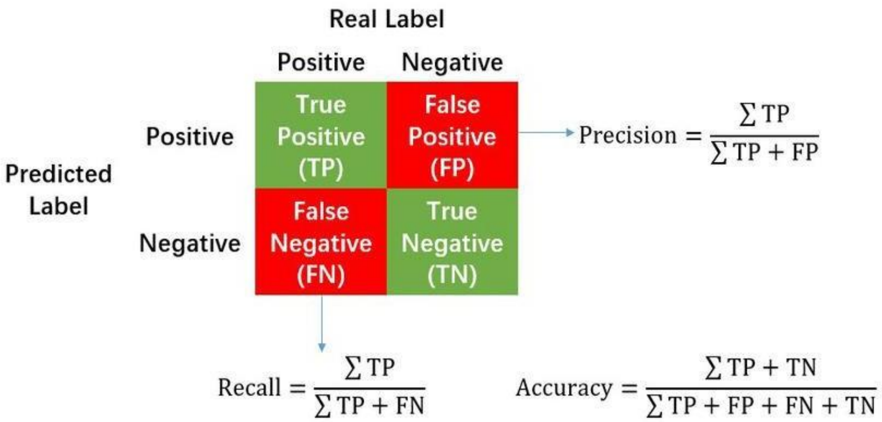
Key Concepts cont…

Evaluation metrics

Evaluation metrics are used to assess the performance of machine learning models. Here are some key metrics:

- **Accuracy**
  - The proportion of correct predictions out of all predictions made.
- **Precision**
  - The proportion of true positive predictions out of all positive predictions made by the model.
- **Recall**
  - The proportion of true positive predictions out of all actual positive cases in the dataset.
- **F1 Score**
  - The harmonic mean of precision and recall, providing a balance between the two metrics.



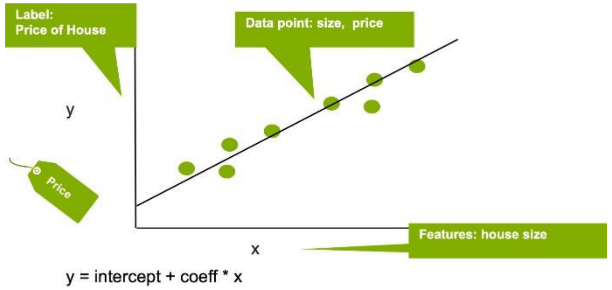


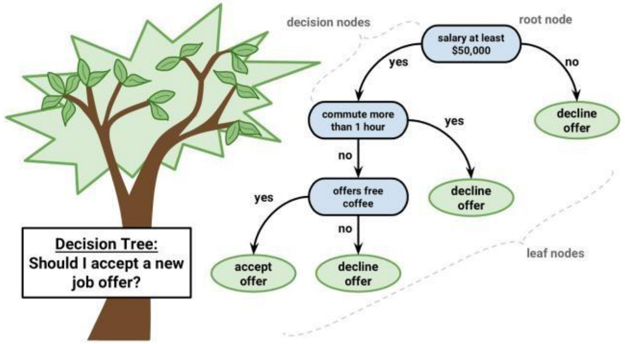
$$F1 = \frac{2 \times Precision \times Recall}{Precision + Recall}$$

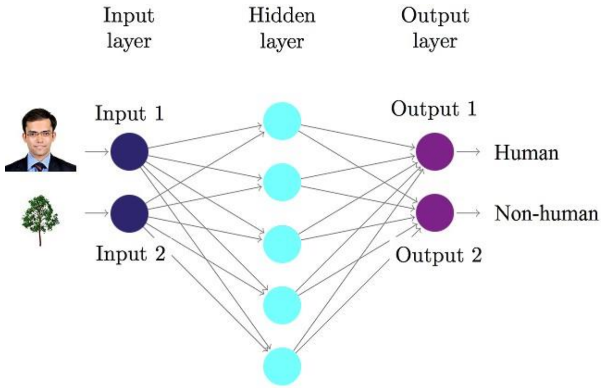
Common Algorithms

Supervised Learning

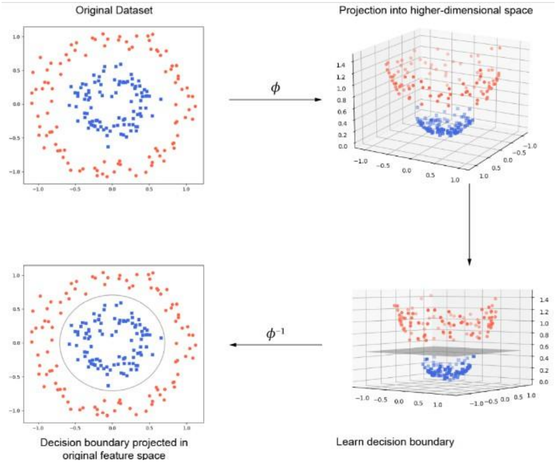
- **Linear Regression**: Predicting continuous values.
- **Decision Trees:** Making decisions based on data splits.
- **Support Vector Machines (SVM):** Classifying data points.
- **Neural Networks:** Mimicking brain functions for complex tasks.

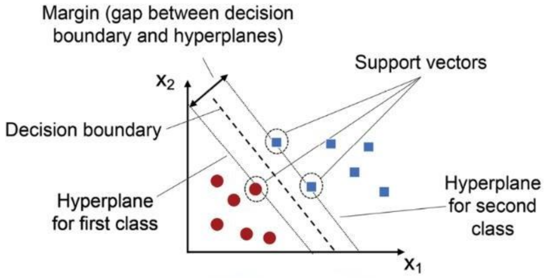




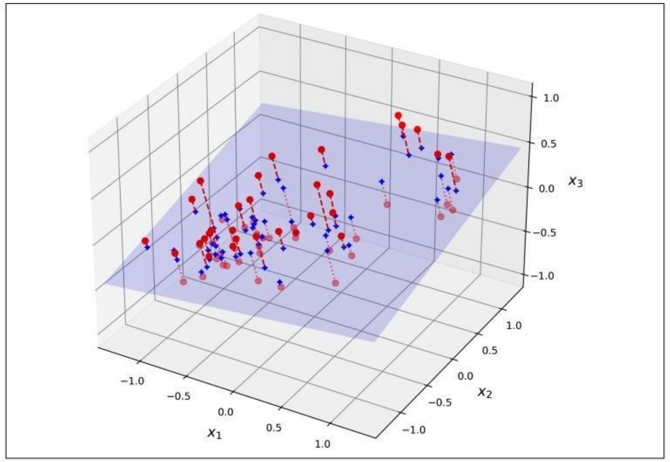


Model for Neural network Image recognition for human and non-human



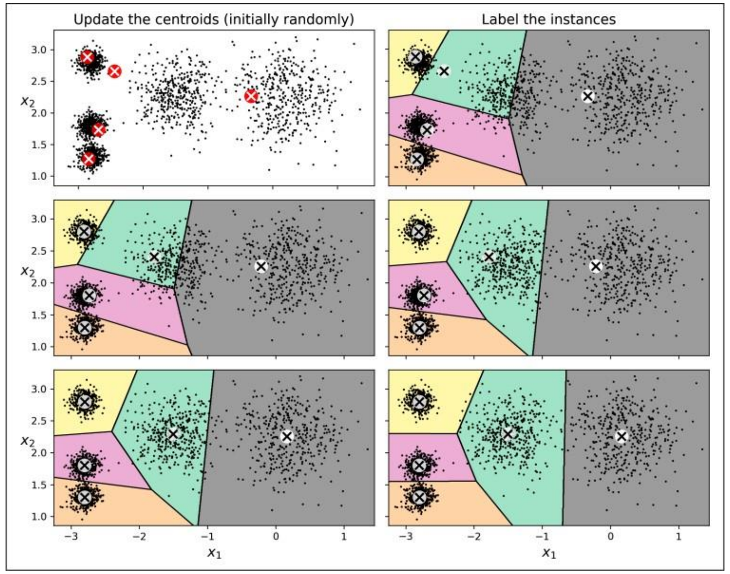


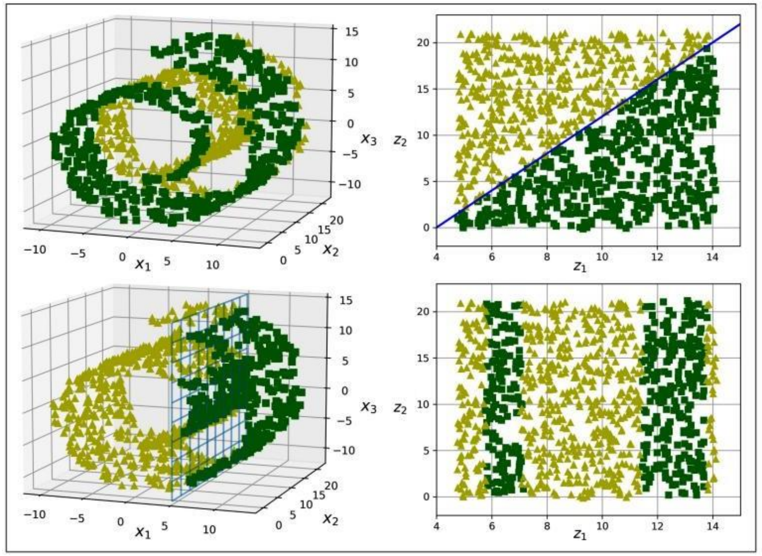
Common Algorithms cont…

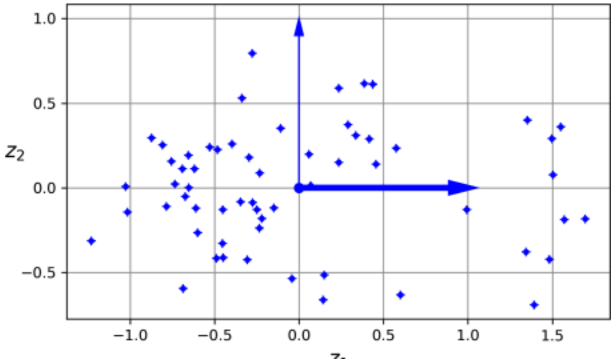


Unsupervised Learning

- **K-Means Clustering:** Grouping similar data points.
- **Principal Component Analysis (PCA):** Reducing dimensionality.



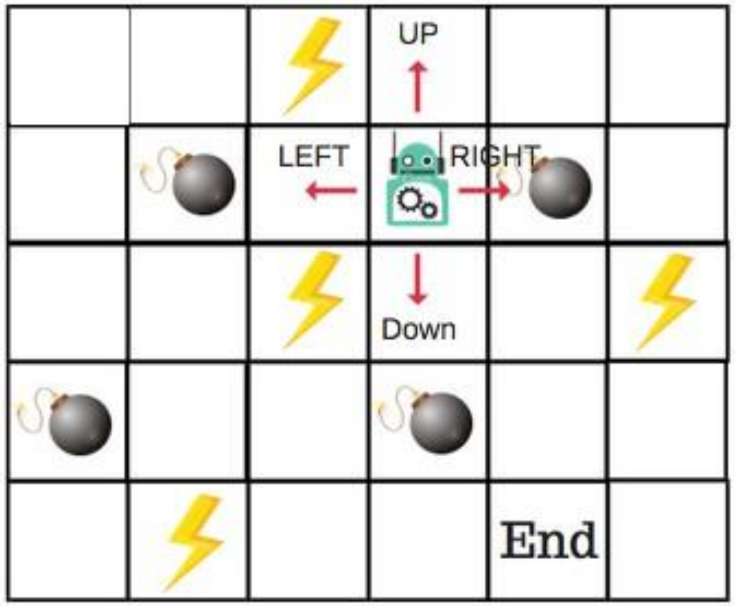


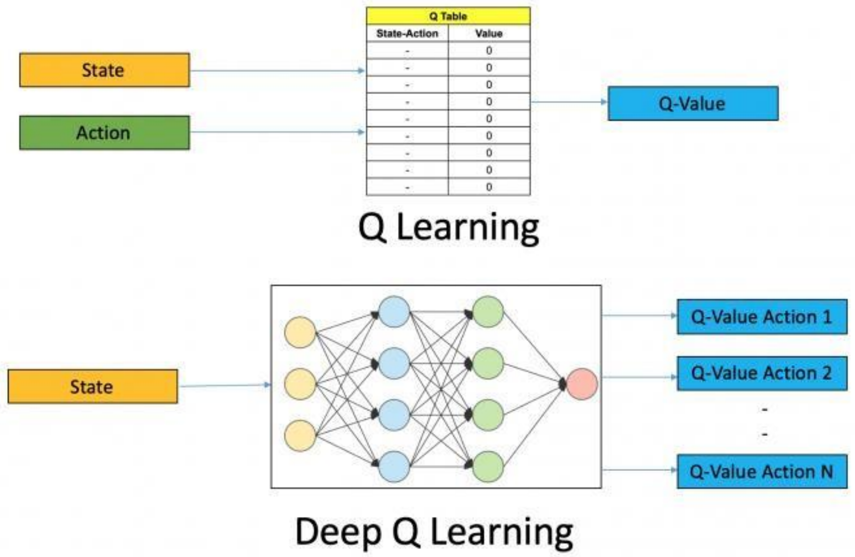


Common Algorithms cont…

Reinforcement Learning

- **Q-Learning:** Learning optimal actions.
- **Deep Q-Networks (DQN):** Advanced game-playing models.





Data Preprocessing

- **Cleaning the Data**
  - Removing duplicates, correcting errors.
- **Feature Scaling and Normalization**
  - Standardizing data ranges.
- **Feature Engineering**
  - Creating new features from existing data.

$$x_{\text{norm}} = \frac{x - \min(x)}{\max(x) - \min(x)}$$

#	Emp	Age	Salary
1	Emp1	44	73000
2	Emp2	27	47000
3	Emp3	30	53000
4	Emp4	38	62000
5	Emp5	40	57000
6	Emp6	35	53000
7	Emp7	48	78000

Normalization

Age	Normalized Age	Salary	Normalized Salary
44	0.80952381	73000	0.838709677
27	0	47000	0
30	0.142857143	53000	0.193548387
38	0.523809524	62000	0.483870968
40	0.619047619	57000	0.322580645
35	0.380952381	53000	0.193548387
48	1	78000	1
	Range 0-1		Range 0-1

How to calculate Normalized value?
X = 35, min = 27, max = 48 for column Age.
Xnorm(for 35) = $\frac{35-27}{48-27}$ = 0.3809

#	Id	Name	Birthday	Gender	IsTeacher?	#Students	Country	City
1	111	John	31/12/1990	M	0	0	Ireland	Dublin
2	222	Mery	15/10/1978	F	1	15	Iceland	
3	333	Alice	19/04/2000	F	0	0	Spain	Madrid
4	444	Mark	01/11/1997	M	0	0	France	Paris
5	555	Alex	15/03/2000	A	1	23	Germany	Berlin
6	555	Peter	1983-12-01	M	1	10	Italy	Rome
7	777	Calvin	05/05/1995	M	0	0	Italy	Italy
8	888	Roxane	03/08/1948	F	0	0	Portugal	Lisbon
9	999	Anne	05/09/1992	F	0	5	Switzerland	Geneva
10	101010	Paul	14/11/1992	M	1	26	Ytali	Rome

Missing values

Invalid values

Misfielded values

Misspellings

Uniqueness

Formats

Attribute dependencies

Feature engineering

$$f_{\vec{w},b}(\vec{x}) = w_1 \underbrace{x_1}_{\text{frontage}} + w_2 \underbrace{x_2}_{\text{depth}} + b$$

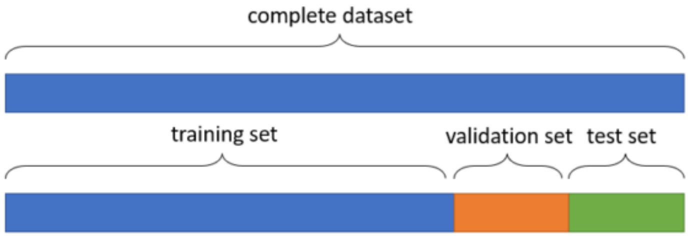
$$area = frontage \times depth$$

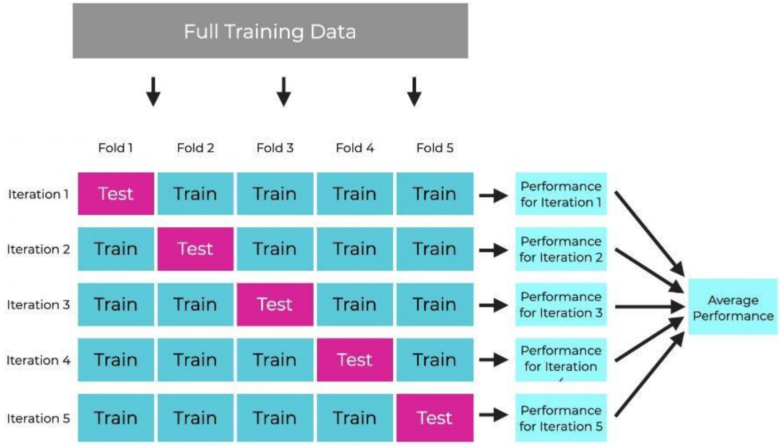
$$\underbrace{x_3 = x_1 x_2}_{\text{new feature}}$$

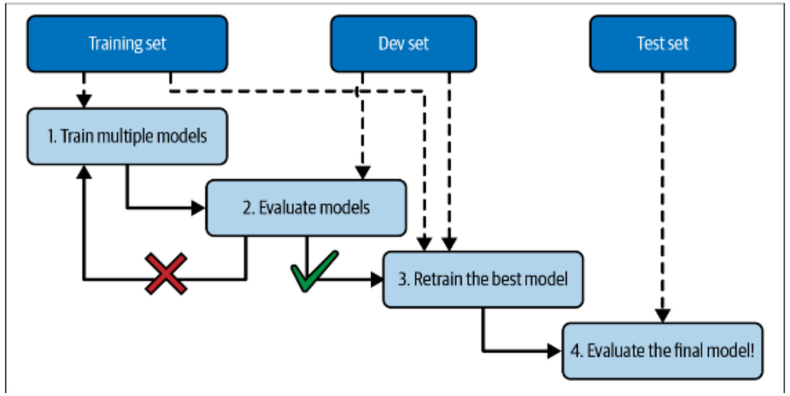
$$f_{\vec{w},b}(\vec{x}) = w_1x_1 + w_2x_2 + w_3x_3 + b$$

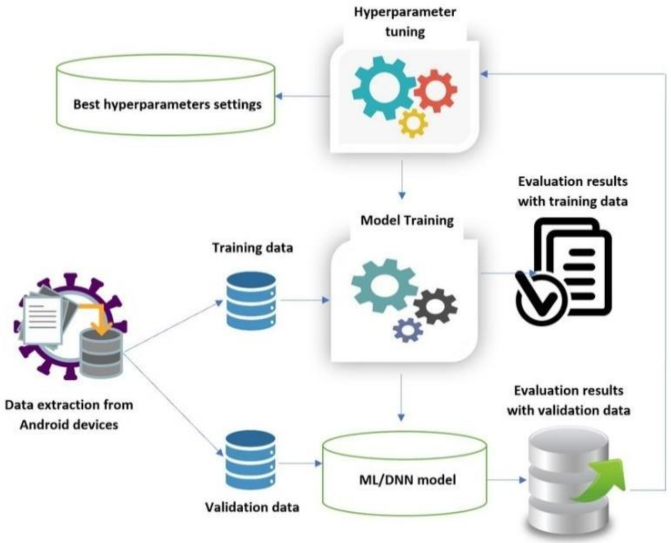
Model Training and Evaluation

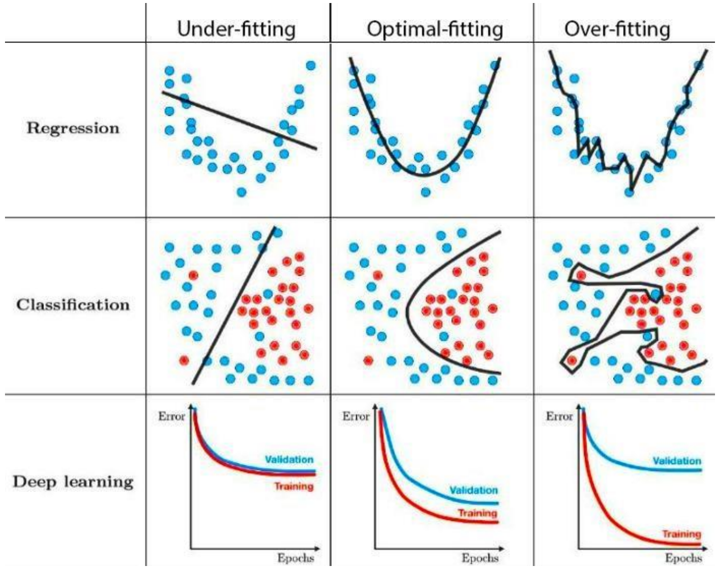
- **Splitting the Dataset**
  - **Training Set:** For learning.
  - **Validation Set:** For tuning.
  - **Test Set:** For final evaluation
- **Cross-Validation**
- **Overfitting vs. Under-fitting**
- **Hyper-parameter Tuning**





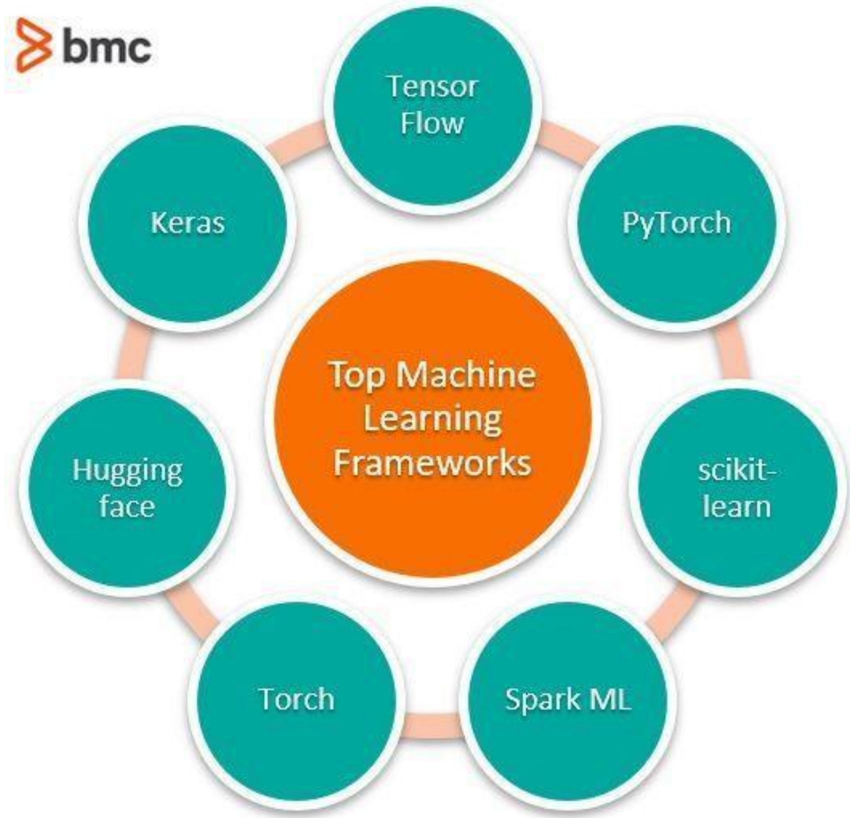






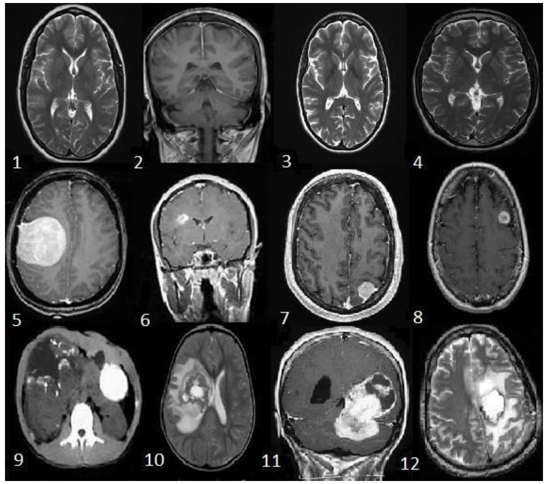
Tools and Frameworks

- **Programming Languages**
  - **Python:** Versatile and widely used.
  - **R:** Statistical analysis.
- **Libraries and Frameworks**.
  - **TensorFlow:** Open-source ML library.
  - **Keras:** High-level neural networks API.
  - **PyTorch**: Deep learning framework.
  - **Scikit-learn:** Simple and efficient tools for data mining and analysis.

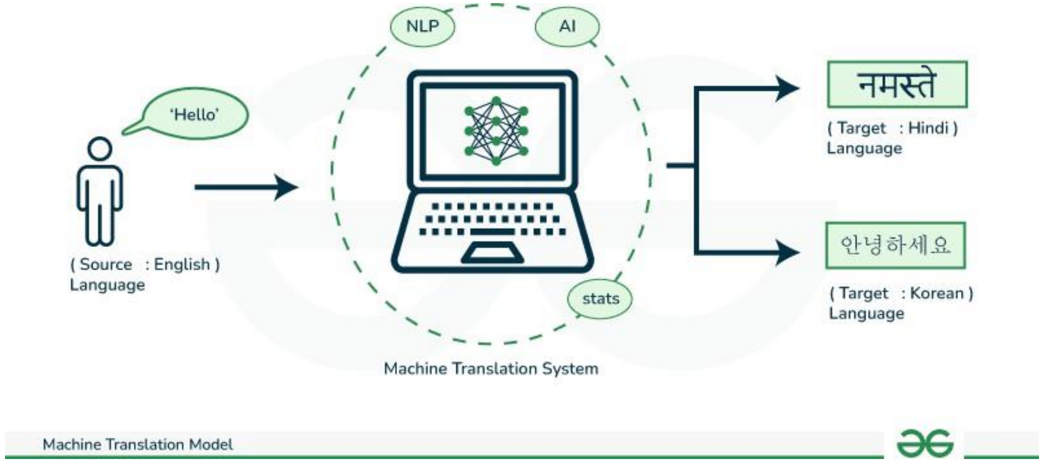


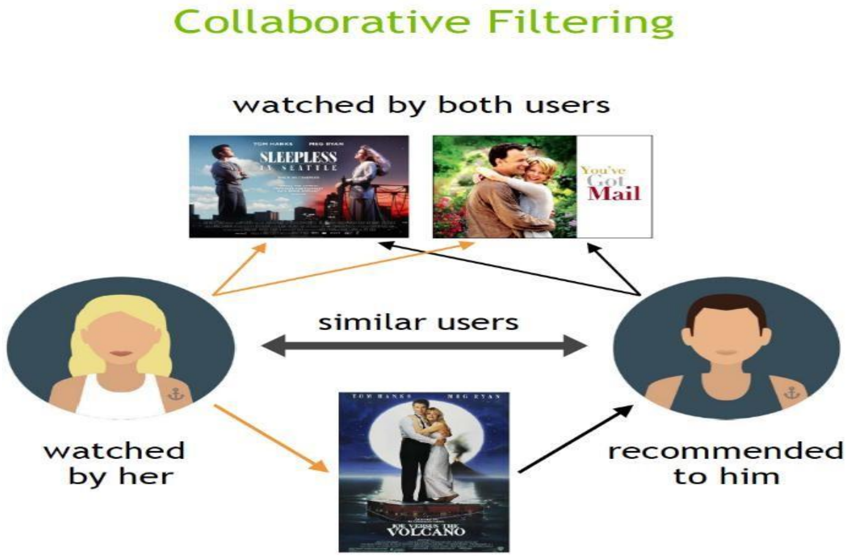
Real-world Applications

- **Healthcare**
  - **Disease Prediction:** Early diagnosis and treatment plans.
- **Finance**
  - **Fraud Detection:** Identifying fraudulent transactions.
- **Retail**
  - **Customer Segmentation:** Targeted marketing.
  - **Recommendation Systems:** Personalized product recommendations.
- **Autonomous Vehicles**
  - Self-driving car technology.
- **Natural Language Processing (NLP)**
  - **Sentiment Analysis:** Understanding emotions in text.
  - **Language Translation:** Translating between languages.



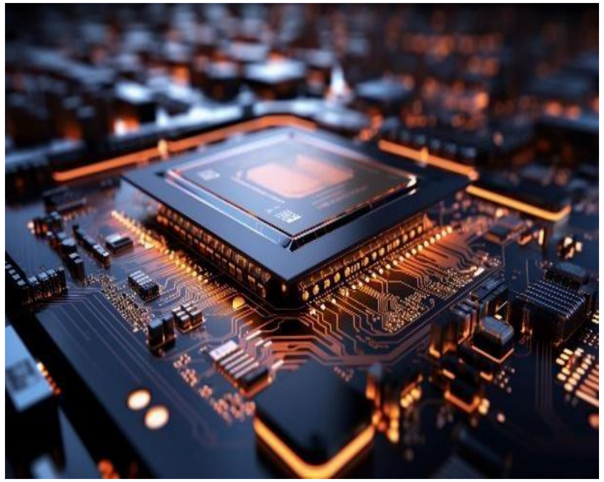
Real-world Applications cont…

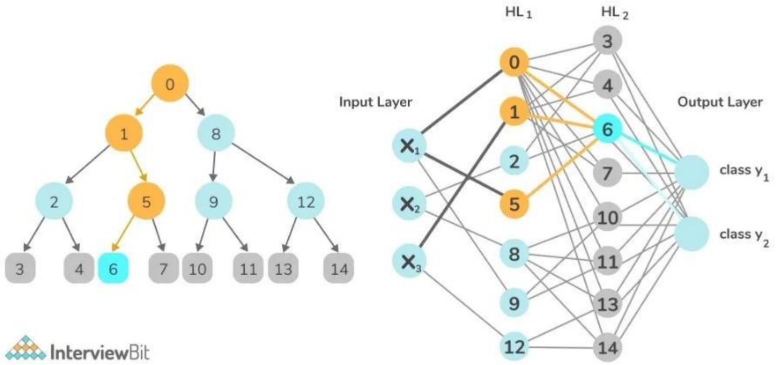




Challenges and Limitations

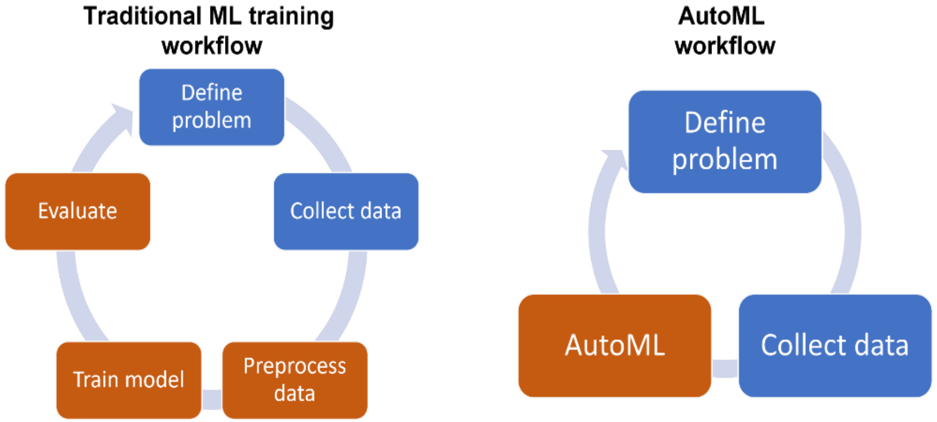
- **Data Quality and Quantity**
  - Need for large, high-quality datasets
- **Computational Power**
  - High resource requirements.
- **Model Interpretability**
  - Difficulty in understanding complex models.
- **Ethical and Privacy Concerns**
  - Issues around data usage and bias..

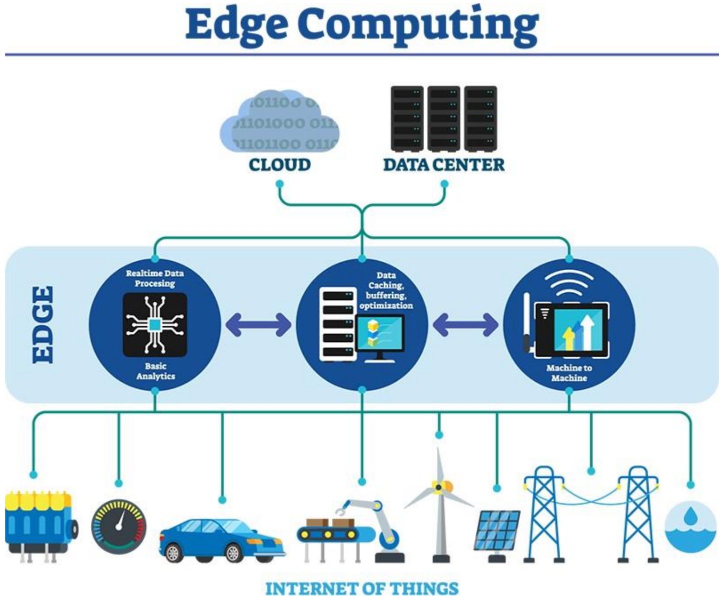


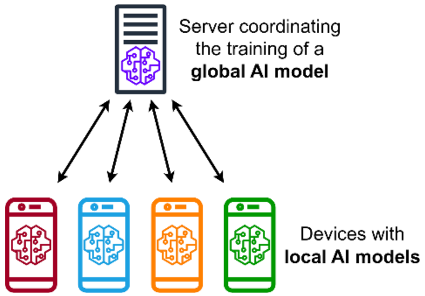


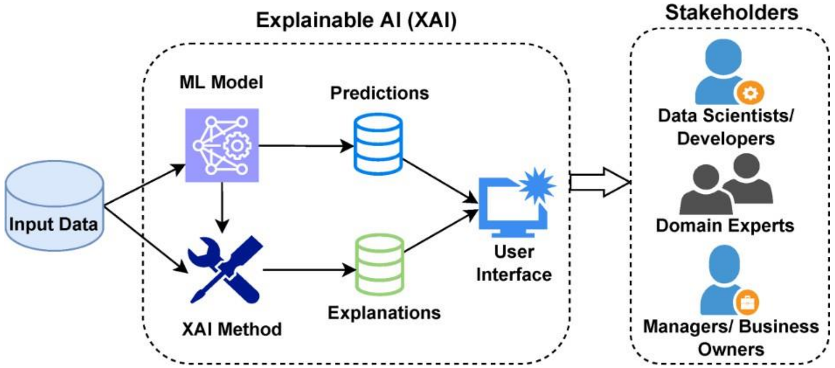
Future Trends

- **AutoML**
  - Automated machine learning processes.
- **Edge Computing**
  - Running ML models on edge devices.
- **Explainable AI (XAI)**
  - Making ML models transparent and interpretable.
- **Federated Learning**
  - Collaborative learning without data sharing.









References

- https://powerunit-ju.com/wp-content/uploads/2021/04/Aurelien-Geron-Hands-On-Machine-Learning-with-Scikit-Learn-Keras-and-Tensorflow_-Concepts-Tools-and-Techniques-to-Build-Intelligent-Systems-OReilly-Media-2019.pdf
- https://www.nvidia.com/en-us/glossary/recommendation-system/
- https://blog.mlq.ai/deep-reinforcement-learning-q-learning/
- https://www.linkedin.com/pulse/explainable-ai-xai-ishad-satyen
- https://learn.microsoft.com/en-us/dotnet/machine-learning/automated-machine-learning-mlnet

Thank You