Introduction to Data Science (machine learning).

1. Artificial Intelligence (AI)

- **Definition**: AI is the creation of applications that can perform specific tasks without human intervention.
- **Key Features**:
    - AI applications are autonomous.
    - They mimic human decision-making and reasoning processes.
- **Examples**:

1. **Netflix Recommendation System**:
    - An AI module analyses user preferences (e.g., action movies) and recommends similar content.
    - Operates independently without direct human involvement.
2. **Self-Driving Cars**:
    - AI modules control vehicle navigation.
    - Tasks include traffic light recognition, obstacle detection, and real-time decision-making.
3. **Amazon/E-commerce Recommendations**:
    - Recommends products based on user purchase history and browsing behavior.

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2. Machine Learning (ML)

- **Definition**: A subset of AI that uses statistical tools and algorithms to analyze and predict outcomes based on data.
- **Key Characteristics**:
    - ML involves identifying patterns and relationships in data.

    - Outputs can be continuous (regression) or categorical (classification).
- **Relationship to AI**:
    - ML is a "smaller circle" within AI's "universe."
    - Any ML project ultimately contributes to AI applications.
- **Examples of Use Cases**:
    - Predicting house prices based on size and number of rooms.
    - Recommending personalized products to users.

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3. Deep Learning

- **Definition**: A subset of ML designed to mimic the human brain using **multi-layered neural networks**.
- **Origins**:
    - In the 1950s, scientists theorized machines could learn like humans.
    - Deep learning was developed to replicate human learning processes.
- **Key Concepts**:
    - **Multi-Layered Neural Networks**:
        - Use multiple layers of interconnected nodes to process data.
        - The complexity enables learning from raw, unstructured data (e.g., images, text).
    - Focuses on learning patterns and features at different levels (e.g., shapes in images, sentence context).
- **Applications**:
    - Image recognition, speech processing, autonomous systems.

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4. Data Science

- **Definition**: An interdisciplinary field that encompasses AI, ML, and deep learning to extract insights and build predictive models.

- **Key Characteristics**:
    - Overlaps with all AI subsets.
    - Relies heavily on mathematics, statistics, and domain knowledge.
    - Tools and techniques:
        - Exploratory Data Analysis (EDA).
        - Feature engineering.
        - Statistical modeling.
- **Role of a Data Scientist**:
    - Works across AI, ML, and deep learning domains.
    - Requires expertise in algorithms, programming, and analytics.

Detailed Explanation of Machine Learning Types

A. Supervised Learning

- **Definition**: A learning method where models are trained on labelled data (data with input-output pairs).
- **Key Features**:
    - Requires **independent features** (inputs) and a **dependent feature** (output).
    - Example: House price prediction.
        - Inputs: House size, number of rooms.
        - Output: House price.
- **Types of Problems**:

1. **Regression**:
    - Output is continuous (e.g., price, temperature).
2. **Classification**:
    - Output is categorical (e.g., pass/fail).

        - **Binary Classification**: Two categories (e.g., pass/fail).
        - **Multi-Class Classification**: More than two categories (e.g., pass, fail, maybe).
- **Key Algorithms**:
    - Linear Regression, Ridge, Lasso, Logistic Regression, Decision Trees, Random Forests, XGBoost.

B. Unsupervised Learning

- **Definition**: A learning method where models find hidden patterns or groupings in unlabeled data.
- **Key Features**:
    - No labeled outputs.
    - Focuses on clustering data into meaningful groups.
- **Example: Customer Segmentation**:
    - Inputs: Salary, Spending Score.
    - Outcome: Groups customers into clusters (e.g., high earners, frequent spenders).
- **Key Algorithms**:
    - K-Means Clustering, Hierarchical Clustering, DBSCAN.

C. Reinforcement Learning

- **Definition**: A trial-and-error-based learning approach where agents learn by interacting with the environment and receiving rewards or penalties.
- **Key Example**:
    - A child learning to walk:
        - Falls and adjusts based on pain (penalty).
        - Successful steps reinforce good behavior.
- **Applications**:

- Gaming AI, robotic process automation, self-driving cars.

Mathematical Foundations

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1. Equation of a Straight Line

- **Standard Form**: $y=mx+c$ = mx + c
  - mm: Slope (rate of change in yy as xx changes).
  - cc: Intercept (where the line crosses the y-axis).
- **Generalized Form**:
  - $y=\beta0+\beta1xy = \beta_0 + \beta_1x$.
  - Equation can represent linear relationships in supervised learning.

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2. Planes and Hyperplanes

- **3D Plane Equation**: $W1X1+W2X2+W3X3+b=0W_1X_1 + W_2X_2 + W_3X_3 + b = 0$.
- **N-Dimensional Plane Equation**: $WTX+b=0W^TX + b = 0$, where:
  - WW: Coefficients vector.
  - XX: Feature vector.
  - bb: Intercept.

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3. Distance from a Plane

- **Formula**: Distance $d=WTS|W|d = \frac{W^T S}{|W|}$, where:
  - SS: Coordinates of the point.
  - WW: Perpendicular vector to the plane.
- **Insights**:
  - Points above the plane have positive distances.
  - Points below the plane have negative distances.

Instance-Based vs. Model-Based Learning

Instance-Based Learning

- **Definition**: Memorizes training data and uses it directly for predictions.
- **Key Characteristics**:
  - No pattern recognition.
  - Relies on similarity to training instances (e.g., nearest neighbors).
- **Examples**: K-Nearest Neighbors (KNN).

Model-Based Learning

- **Definition**: Learns patterns and generalizes for future predictions.
- **Key Characteristics**:
  - Builds a generalized model (e.g., decision boundaries).
  - Faster and more efficient for new predictions.
- **Examples**: Decision Trees, Random Forests.

Key Differences

Aspect	Instance-Based	Model-Based
Learning Method	Memorizes data	Learns patterns
Prediction Speed	Slower	Faster
Storage Requirements	High (full dataset)	Low (compact model)
Generalization Ability	Low	High

Conclusion

- **AI, ML, Deep Learning, and Data Science**:
    - Each contributes to building intelligent applications.
- **Supervised and Unsupervised Learning**:
    - Core approaches to solving regression, classification, and clustering problems.
- **Mathematical Concepts**:
    - Essential for understanding machine learning algorithms.
- **Instance vs. Model-Based Learning**:
    - Highlights different approaches to training and prediction.
