Overview of Machine Learning

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Agenda

- What Is Machine Learning
- History of Machine Learning
- How Does Machine Learning Work
- How Does Machine Learning Benefit Us
- Why Machine Learning Now
- Machine Learning Development Lifecycle
- Course Roadmap

What Is Machine Learning

- A subfield in Artificial Intelligent
- It gives computers the capability to learn without being explicitly programmed
- Focus on developing algorithms to create mathematical models by extracting patterns hidden in the past data
- Computers can use the models to make predictions on the similar data or generate new content

History of Machine Learning

- 1950s
  - Samuel's checker player
  - Selfridge's Pandemonium
- 1960s
  - Neural networks: Perceptron
  - Pattern recognition
  - Learning in the limit theory
  - Minsky and Papert prove limitations of Perceptron
- 1970s
  - Symbolic concept induction
  - Winston's arch learner
  - Expert systems and the knowledge acquisition bottleneck
  - Quinlan's ID3
  - Michalski's AQ and soybean diagnosis
  - Scientific discovery with BACON
  - Mathematical discovery with AM

History of Machine Learning (cont.)

- 1980s
  - Advanced decision tree and rule learning
  - Explanation-based Learning (EBL)
  - Learning and planning and problem solving
  - Utility problem
  - Analogy
  - Cognitive architectures
  - Resurgence of neural networks (connectionism, backpropagation)
  - Valiant's PAC Learning Theory
  - Focus on experimental methodology

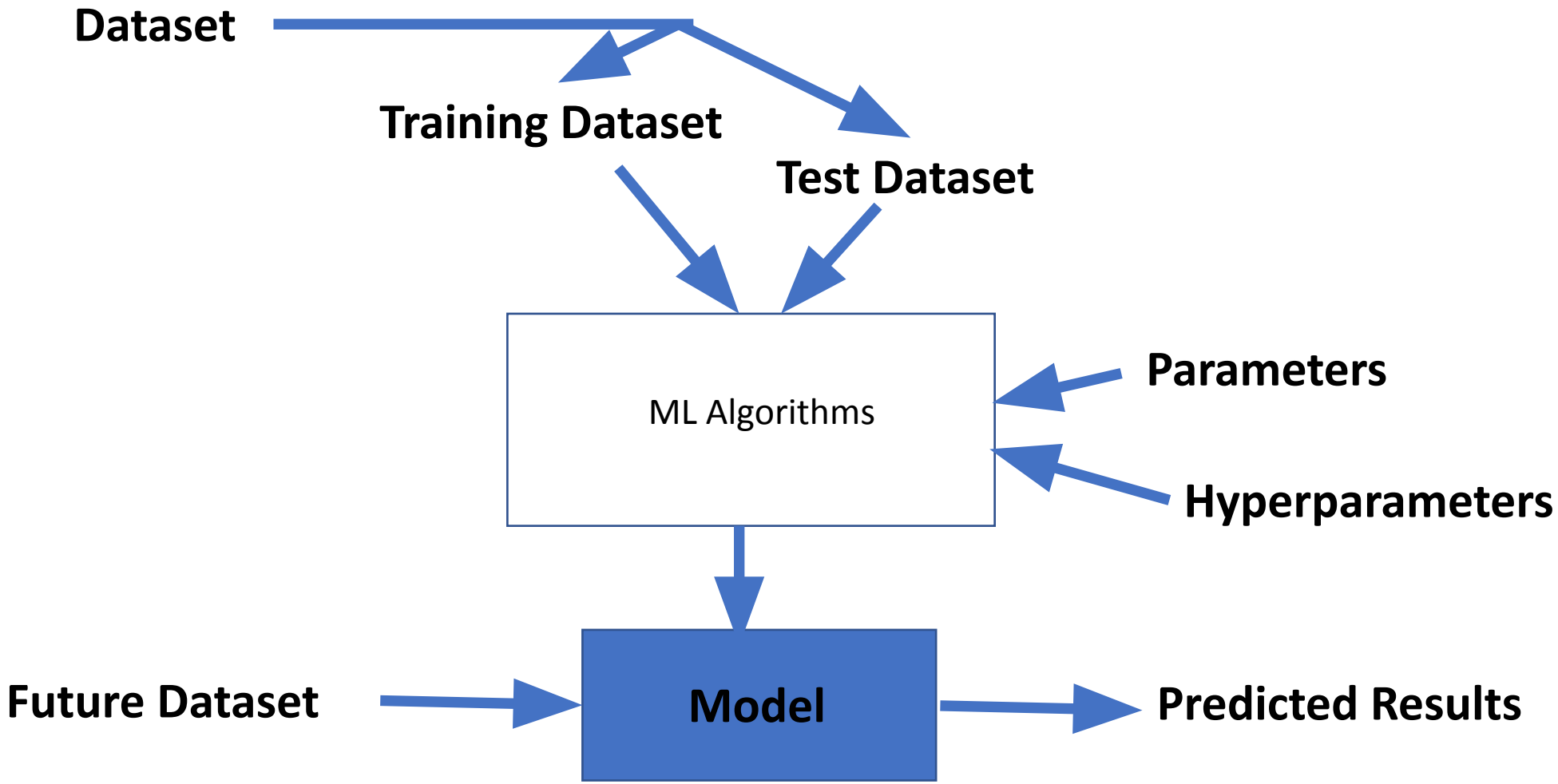
History of Machine Learning (cont.)

- 1990s
  - *Data mining*
  - Adaptive software agents and web applications
  - *Text learning*
  - *Reinforcement learning (RL)*
  - Inductive Logic Programming (ILP)
  - *Ensembles: Bagging, Boosting, and Stacking*
  - *Bayes Net learning*
- 2000s
  - *Support vector machines & kernel methods*
  - Graphical models
  - Statistical relational learning
  - Transfer learning
  - Sequence labeling
  - Collective classification and structured outputs
  - Computer Systems Applications (Compilers, Debugging, Graphics, Security)
  - E-mail management
  - Personalized assistants that learn
  - Learning in robotics and vision

History of Machine Learning (cont.)

- 2010s
  - *Deep learning systems*
  - *Learning for big data*
  - *Bayesian methods*
  - Multi-task & lifelong learning
  - *Applications to vision, speech, social networks, learning to read*, etc.
- 2020s
  - *Robotics*
  - *Self-driving cars*
  - *Data science*
  - *Generative AI*
  - ???

How Does Machine Learning Work



Dataset

- Represents a collection of data in a table format
  - Each row is a data point
  - Each column is a feature of a data point
- Dataset types
  - Text
  - Image
  - etc.
- Data types of features
  - Nominal
  - Binary
  - Ordinal
  - Numeric

ML Algorithms

- Supervised Learning
  - Regression analysis
  - Classification (e.g., logistic regression, decision trees, naïve-bayes classifier)
- Unsupervised Learning (e.g., K-mean)
- Reinforcement Learning
- Artificial Neural Network

Discriminative vs Generative Algorithms

Params	GENERATIVE ALGORITHM	DISCRIMINATIVE ALGORITHM
Objective	Models the joint probability distribution of the input characteristics and labels in a generative manner.	Modeling the conditional probability distribution of labels given input attributes is the main focus of discriminative modeling.
Methodology	Creates new samples by learning the distribution of the underlying data.	Acquires the threshold of judgment that distinguishes various classes or categories.
Application	Text generation and image synthesis are examples of generative tasks.	Used in activities like sentiment analysis and image categorization.
Strength	Effective with inadequate or missing data	Excellent at distinguishing between classes or categories is discrimination.
Weakness	May have trouble distinguishing different classes in large datasets.	Less useful when dealing with incomplete or missing data.

ML Algorithms - Parameters

- Model parameters
  - Regression analysis
  - Logistic regression
  - SVM etc.
- Hyperparameters
  - Kernal
  - Regularization

How Does Machine Learning Benefit Us

- Data science
- Data mining
- Robotics
- Self-driving cars
- Generative AI
- etc.

Data Science and Machine Learning

- Data science deals with a tremendous amount of data to
  - find different and unseen patterns,
  - derive information, and
  - make business decisions
- We use machine learning algorithms in data science when we want to make accurate estimates about a given set of data
- For instance, if we need to predict whether a patient has cancer-based on the results of their bloodwork

Robotics and Machine Learning

- Robotics has the capabilities:
  - Object recognition and manipulation
  - Autonomous navigation and obstacle avoidance
  - Human-robot collaboration
  - Predictive maintenance and self-learning
- Machine learning technologies in particular, the reinforcement learning are used to implement these capabilities
- Self-driving cars

Generative AI and Machine Learning

- Generative AI is all about make an AI system that can create fresh, creative stuff that can sometimes be hard to tell apart from human-made things.
- Generative AI has the capacity to understand human text and produce human readable outputs.
- Generative AI uses *deep learning*, especially *Generative Adversarial Networks (GANs)* and *Recurrent Neural Networks (RNNs)* to create the Large Language Models (LLMs) with large datasets
- Examples of Generative AI
  - ChatGPT
  - Bing AI
  - DALL-E 2

Why Machine Learning Now

- Availability of Large Amount of Historical Data
- Advanced Programming Languages
- Graphical Processing Unit (GPU)
- Big Data Processing Frameworks

Major Tasks to Build Good Models

- Dataset cleaning
- Apply the following feature transformation tasks on datasets to create Training (Test) Data
  - Feature encoding
  - Feature scaling
  - Feature selection/Feature extraction
    - The number of features of training data determines the model complexity
    - The model complexity determines if a model is *underfitting*/*overfitting*
- Build/fine-tune the model
  - Selection of ML algorithms
  - Hyperparameter Tuning

Machine Learning Lifecycle

- Collect Data
- Pre-process Data
  - Data Visualization of Feature Characteristics/Correlation
  - Feature Scaling/Normalization/Imputation
  - Feature Selection/Extraction
- Select ML Algorithm
- Build Model
  - Train the Model
  - Hyperparameter Tuning/Model Validation
- Deploy Model
- Evaluate Model

Course Roadmap

- Data Pre-Processing
- Regression Analysis
- Classification Algorithms
- Model Validation/Fine-tuning
- Clustering Algorithms
- Artificial Neural Networks