Machine Learning
ICT-4261

By-
Dr. Jesmin Akhter
Professor
Institute of Information Technology
Jahangirnagar University

Grading Policy

- ✔ Attendance =10%
- ✔ Exercise test =10%
  - Instant test
  - Assignment
  - Presentation
- ✔ Class Test (Average of three) =20%
- ✔ Final Examination =60%

==========

=100%

Exam schedule

Tutorial	Date and Time
Tutorial-01	After 2 classes
Tutorial-02	After 11 classes
Tutorial-03	After 18 classes

NB: Schedule may change

Contents

The course will mainly cover the following topics:

- ✔ A Gentle Introduction to Machine Learning
- ✔ Linear Regression
- ✔ Logistic Regression
- ✔ Naive Bayes
- ✔ Support Vector Machines
- ✔ Decision Trees and Ensemble Learning
- ✔ Clustering Fundamentals
- ✔ Hierarchical Clustering
- ✔ Neural Networks and Deep Learning
- ✔ Unsupervised Learning……

Outline

- ✔ A Gentle Introduction to Machine Learning
  - What is Machine Learning
  - classic and adaptive machines
  - Supervised learning
  - Unsupervised learning

What is Machine Learning

- ✔ "Machine Learning is the field of study that gives computers the ability to learn without being explicitly programmed." -Arthur Samuel (1959)
- ✔ **Machine learning is a** sub-field of artificial intelligence (AI) **,** which enables the machine
  - To automatically learn from data,
  - Improve performance from past experiences without being explicitly programmed, and
  - Make predictions.
- ✔ Machine learning focuses on the use of huge amount of **data and a set of algorithms** to **imitate the way that human learns**, gradually improving its accuracy.
- ✔ Machine learning algorithms are typically created using frameworks TensorFlow and PyTorch that accelerate solution.

Difference between Traditional Programming and Machine Learning?

In Traditional Programming:

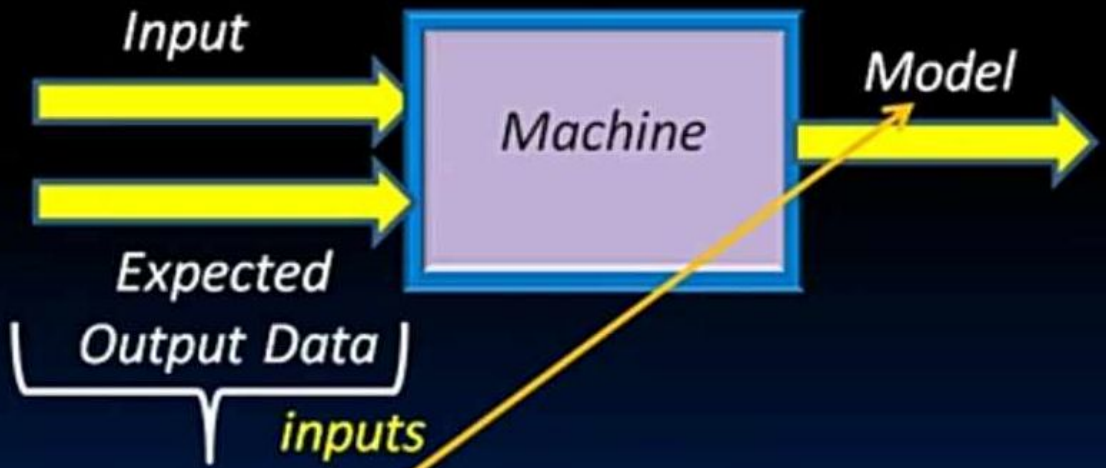
1. We, human beings write programs.

These programs take inputs and generate output as per the code we have written.

2. The Programs written once will not be changed until and unless they are updated manually by somebody.

In Machine Learning:

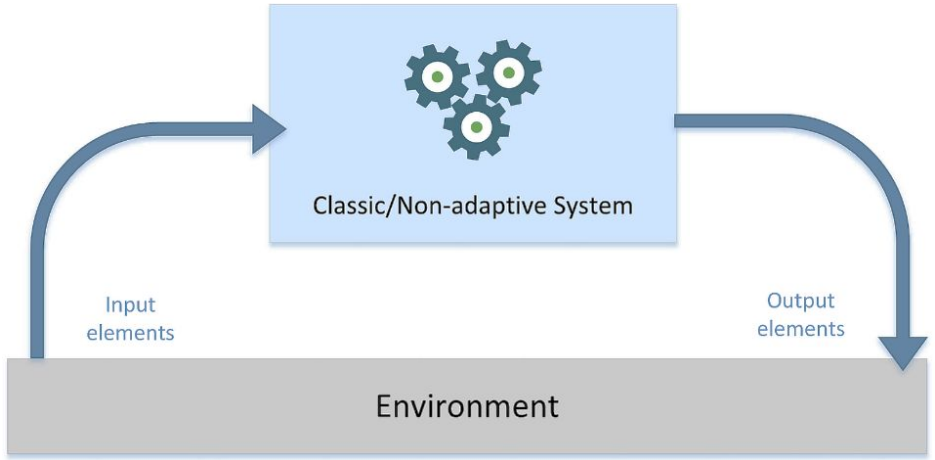
1. It is an automatic process.



2. These Models are nothing but programs generated by algorithms without being explicitly programmed by any human being.
3. These models continuously evolve into better models automatically as the amount of quality data increases.

Classic machines

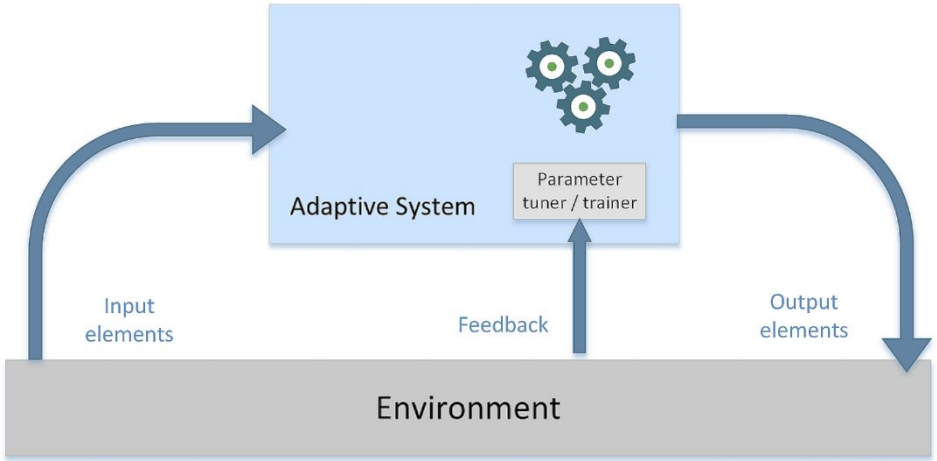
- ✔ This is the generic representation of a classical system that receives some input values, processes them, and produces output results:



- ✔ Classic machines examine data inputs according to a predetermined set of rules, finding patterns and relationships in data using statistical techniques that can be used to generate predictions or choices. This type of machines are static / robotic in nature
  - Support vector machines, decision trees, and logistic regression are some of the most used classical machine-learning techniques.

Adaptive machines

- ✔ Here's a schematic representation of an adaptive system:



- ✔ Such a system isn't based on static or permanent structures (model parameters and architectures) but rather on a continuous ability to adapt its behavior to external signals (datasets or real-time inputs) and, like a human being, to predict the future using uncertain and fragmentary pieces of information.
- ✔ Artificial neural networks, which are designed after the composition and operation of the human brain, are used by adaptive machines. These neural networks are made up of layers of connected nodes, or neurons, where each one carries out a straightforward calculation. The neurons are arranged in layers, and each layer processes the input data in a unique way.

When Do We Need Machine Learning?

- ✔ When do we need machine learning rather than directly program our computers to carry out the task at hand?
  - **Two aspects of a given problem** may call for the use of programs that learn and improve on the basis of their "experience":
  - **the problem's complexity** and **the need for adaptivity.**
  - **Tasks That Are Too Complex to Program.**
    - **Tasks Performed by Animals/Humans:**
      - There are numerous tasks that we human beings perform routinely, include driving, speech recognition, and image understanding. In all of these tasks, state of the art machine learning programs, programs that "learn from their experience," achieve quite satisfactory results
    - **Tasks beyond Human Capabilities:**
      - Tasks with very large and complex data sets: astronomical data, turning medical archives into medical knowledge, weather prediction, analysis of genomic data, Web search engines, and electronic commerce.
      - With more and more available digitally recorded data, it becomes obvious that there are treasures of meaningful information buried in data archives that are way too large and too complex for humans to make sense of.
      - Learning to detect meaningful patterns in large and complex data sets is a promising domain

When Do We Need Machine Learning?

- **Adaptivity.**
  - One limiting feature of programmed tools is their rigidity – once the program has been written down and installed, it stays unchanged. However, many tasks change over time or from one user to another.
  - Machine learning tools – programs whose behavior adapts to their input data – offer a solution to such issues; they are, by nature, adaptive to changes in the environment they interact with.
    - Decode handwritten text, where a fixed program can adapt to variations between the handwriting of different users; spam detection programs - adapting automatically to changes in the nature of spam e-mails; and speech recognition programs.

Types of machine learning

- ✔ There are four major categories:
  - **Supervised Machine Learning**:
    - The training data you feed to the algorithm includes **the desired solutions,** called **labels**.
    - A typical supervised learning task is **classification**.
      - The spam filter is a good example. It is trained with many example emails along with their class (spam or not spam), and it must learn how to classify new emails.
  - **Unsupervised Machine Learning**:
    - The training data is **unlabeled**.
    - Anomaly detection—detecting unusual credit card transactions to prevent fraud, catching manufacturing defects, or automatically removing outliers from a dataset before feeding it to another learning algorithm.
    - The system is shown mostly normal instances during training, so it learns to recognize them and when it sees a new instance it can tell whether it looks like a normal one or whether it is likely an anomaly.

Types of machine learning

- **Semi-Supervised Machine Learning**:
  - Some algorithms can deal with partially labeled training data, usually a lot of unlabeled data and a little bit of labeled data. This is called semisupervised learning.
  - Example: Text Classification
    - Sentiment analysis (or opinion mining) is a natural language processing (NLP) technique used to determine whether data is positive, negative or neutral. Sentiment analysis is often performed on textual data to help businesses to **monitor brand and product** from the sentiment in customer feedback, and understand customer needs.
  - Web content classification-With SSL, Google Search finds content that is most relevant to a particular user query.

Types of machine learning

- **Reinforcement Learning**:
  - The learning system, called an agent in this context, can observe the environment, select and perform actions, and get rewards in return or penalties in the form of negative rewards. It must then learn by itself what is the best strategy, called a policy, to get the most reward over time.

  - Self-driving cars to learn from their own experience and adapt to changing situations. Self-driving cars are autonomous vehicles that can navigate roads and traffic without human intervention. To achieve this, they need to perceive the surrounding environment, plan the optimal route, and execute the appropriate actions. RL is a natural fit for this task, as it can enable self-driving cars to learn from their own experience and adapt to changing situations

Supervised machine learning

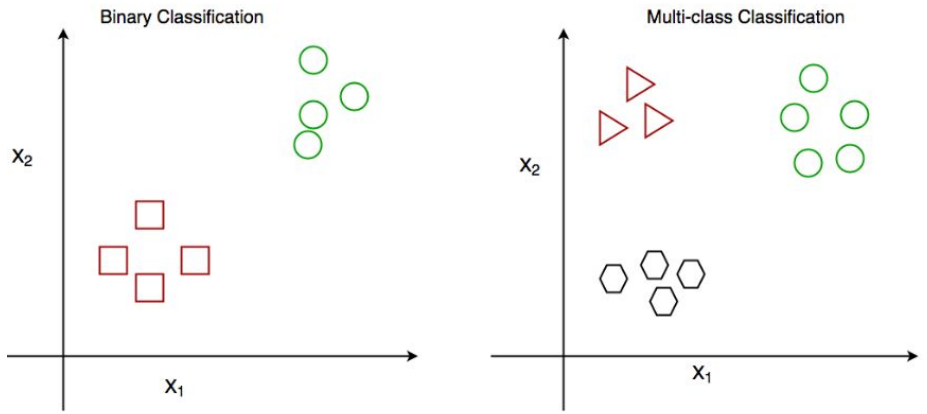
- ✔ **Supervised learning**, also known as supervised machine learning, is defined by its use of labeled datasets to train algorithms to classify data or predict outcomes accurately.
- ✔ Supervised machine learning has two key components: first is **input data** and second corresponding **output labels**. The goal is to build a model that can learn from this labeled data to make predictions or classifications on new, unseen data.
- ✔ The labeled data consists of input features **(also known as independent variables or predictors)** and the corresponding output labels **(also known as dependent variables or targets)**.
- ✔ The model's objective is to capture patterns and relationships between the input features and the output labels, allowing it to generalize and make accurate predictions on unseen data.

Supervised machine learning

- ✔ There are two main types of supervised learning problems: they are **classification** that involves predicting a class label and **regression** that involves predicting a numerical value.
- ✔ **Classification** algorithms are used to **predict/Classify the discrete values** such as Male or Female, True or False, Spam or Not Spam, etc
- ✔ **Regression** algorithms are used to **predict the continuous** values such as price, salary, age, etc.

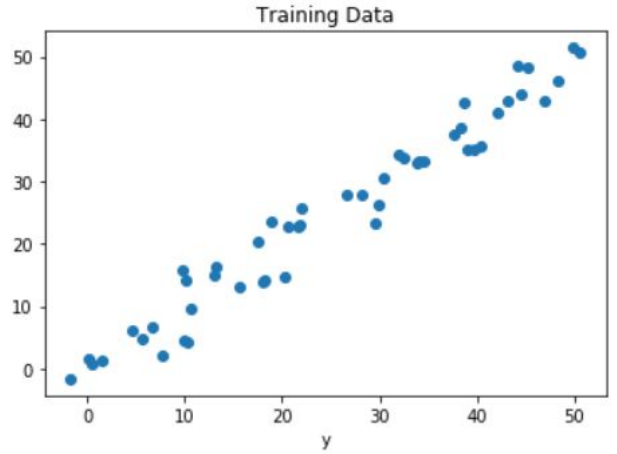
Classification and Regression

- ✔ The **classification** process deals with problems where the data can be divided into binary or multiple discrete labels.
- ✔ Suppose we want to predict the possibility of the winning of a match by Team A on the basis of some parameters recorded earlier. Then there would be two labels Yes and No.



Binary Classification and Multiclass Classification

- ✔ **Regression** is the process of finding a model or function for distinguishing the data into continuous real values instead of using classes or discrete values. It can also identify the distribution movement depending on the historical data.
- ✔ An example in regression, where we are finding the possibility of rain in some particular regions with the help of some parameters recorded earlier. Then there is a probability associated with the rain.



Regression of Day vs Rainfall (in mm)

How Does Supervised Learning Work?

Supervised machine learning typically follows a series of steps to train a model and make predictions.

✔ **Data Collection and Labeling**

- The first step in supervised machine learning is collecting a **representative and diverse dataset.** This dataset should include a **sufficient number of labeled examples** that cover the range of inputs and outputs **the model will encounter in real-world scenarios**.
- The labeling process involves assigning the correct output label to each input example in the dataset. This can be a **time-consuming and labor-intensive task**, depending on the complexity and size of the dataset.

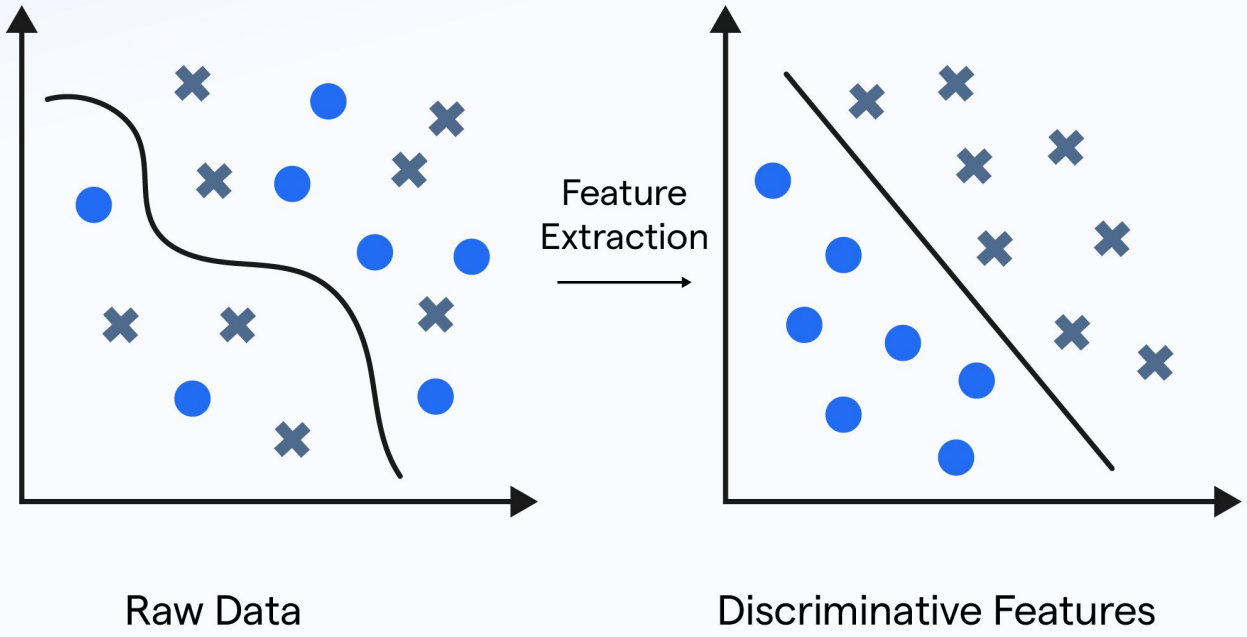
✔ **Training and Test Sets**

- Once the dataset is collected and labeled, it is divided into two subsets: the training set and the test set.
  - The training set is used to **train the model** and it serves as the basis for the model to **learn patterns and relationships** between the input features and the output labels,
  - While the test set is used to assess the model's generalization ability and its performance on new, unseen data.

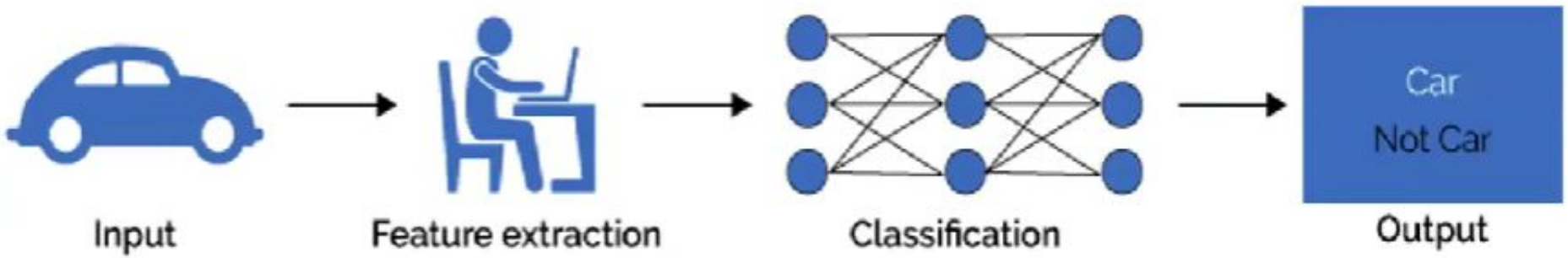
How Does Supervised Learning Work?

- ✔ **Feature Extraction**
  - Before training the model, it is essential to **extract relevant features from the input data**.
  - Feature extraction involves **selecting or transforming** the input features to capture the most relevant information for the learning task.
  - Feature extraction refers to the process of transforming **raw data into numerical features** that can be processed while preserving the information in the original data set
  - This process enhances the model's predictive performance and reduce the dimensionality of the data.
- ✔ **Model Selection and Training**
  - Choosing an appropriate machine learning algorithm is crucial for the success of supervised learning. Different algorithms have different strengths and weaknesses, making it important to select the one that best fits the problem at hand.
  - Once the algorithm is selected, the model is trained using the labeled training data. During the training process, the model **learns the underlying patterns and relationships in the data by adjusting its internal parameters**.
  - The objective is to **minimize the difference** between the **predicted outputs and the true labels in the training data.**

Feature Extraction

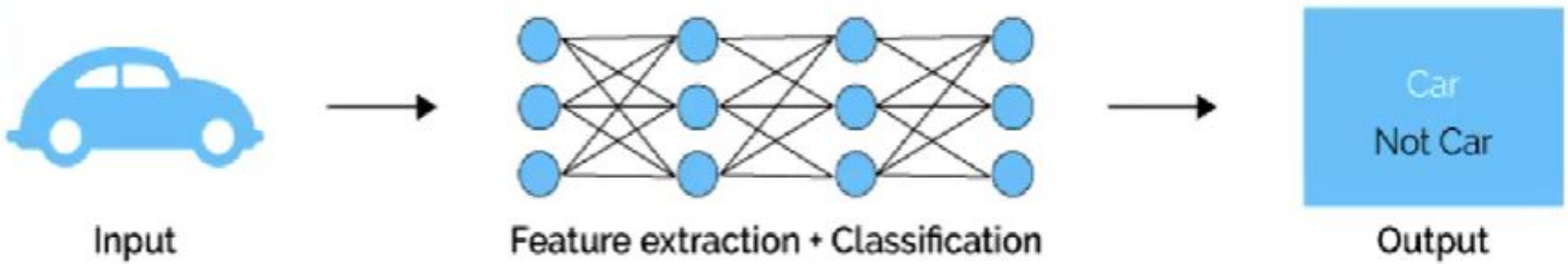


Machine Learning



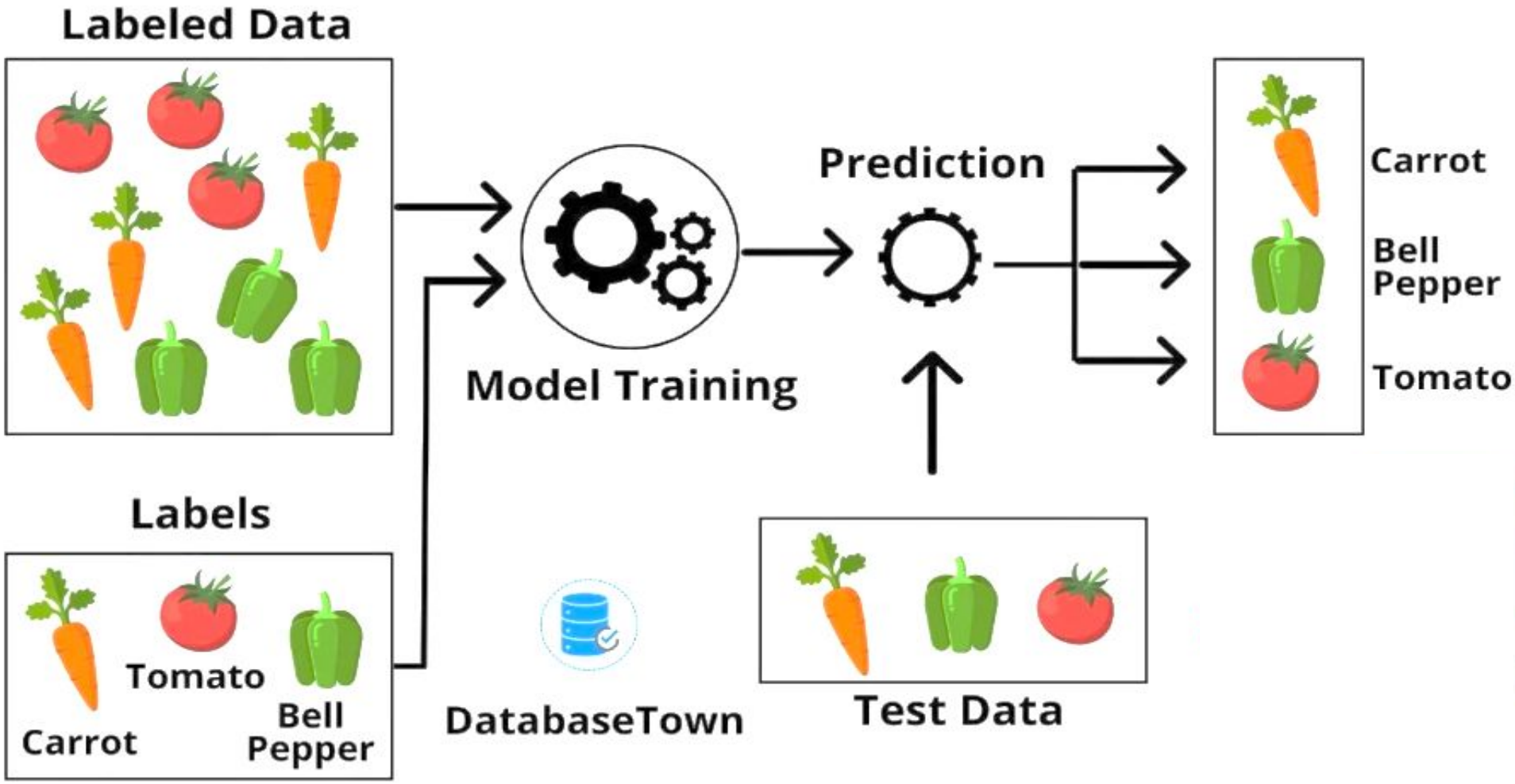
Input → Feature extraction → Classification → Output

Deep Learning



Input → Feature extraction + Classification → Output

How Does Supervised Learning Work?



How Does Supervised Learning Work?

- ✔ **Prediction and Evaluation**
  - Once the model is trained, it can be used to make predictions on new, unseen data. The input features of the unseen data are fed into the trained model, which generates predictions or classifications based on the learned patterns.
  - To evaluate the model's performance, the predicted outputs are compared against the true labels of the unseen data.
  - Common evaluation metrics include accuracy, precision, recall, and F1 score, depending on the nature of the learning task.

Supervised Learning Algorithms

Supervised machine learning includes various algorithms, each suited for different types of problems. Commonly used algorithms are:

- ✔ **Linear Regression**
  - Linear regression is a popular algorithm used for predicting continuous output values. It establishes a linear relationship between the input features and the target variable, allow us to make predictions based on this relationship.
- ✔ **Logistic Regression**
  - Logistic regression is employed when the **output variable is binary or categorical.** It models the relationship between the input features and the probability of a particular outcome using a **logistic function**. Logistic Regression generates a value where output is always either 0 or 1. So it is a **classification algorithm**.
- ✔ **Decision Trees**
  - Decision trees are tree-like models that use a hierarchical structure to make decisions. They split the data based on different features and create a tree-like structure, enabling **classification or regression tasks.** It is also used in Random Forest to train on different subsets of training data

Supervised Learning Algorithms

- ✔ **Random Forests**
  - Random forests are an **ensemble** learning method that **combines multiple decision trees**. They **improve the predictive accuracy** by **aggregating predictions from multiple trees**, reducing **overfitting** and increasing robustness.
- ✔ **Support Vector Machines (SVM)**
  - Support Vector Machines are effective for **both classification and regression tasks**. They create hyperplanes or decision boundaries that maximize the margin between different classes, allowing for accurate predictions. The hyperplane tries that the margin between the closest points of different classes should be as maximum as possible.
- ✔ **Naive Bayes**
  - Naive Bayes algorithms are based on Bayes' theorem and are commonly used for classification tasks. They assume that the input features are independent, making predictions based on the probability of each class.

Supervised Learning Algorithms

- ✔ **K-Nearest Neighbors (KNN)**
  - The K-NN algorithm works by finding the K nearest neighbors to a given data point based on a distance metric, such as Euclidean distance. The class or value of the data point is then determined by the majority vote or average of the K neighbors
- ✔ **Neural Networks**
  - It is a type of machine learning process, called deep learning, that uses interconnected nodes or neurons in a layered structure , enabling them to learn complex patterns and relationships that resembles the human brain. Neural networks can analyze human **speech** despite varying **speech** patterns, pitch, tone, language, and accent
- ✔ **Gradient Boosting Algorithms**
  - Gradient boosting algorithms, such as Gradient Boosted Trees and XGBoost, are ensemble methods that sequentially build/train models, each focusing on the errors of the previous models. They are effective for classification and regression tasks, providing high predictive accuracy.
  - It combines several weak learners into strong learners.
  - Gradient boosting played a crucial role in building recommendation systems for multi-billion companies like Netflix.

Applications

Supervised machine learning finds application in various domains. Here are some examples:

- ✔ **House prices**
  - One practical example of supervised learning problems is predicting house prices. How is this achieved?
  - First, we need data about the houses: square footage, number of rooms, whether a house has a garden or not, location and so on. We then need to know the prices of these houses, i.e. the corresponding labels. By leveraging data/ analyzing data coming from thousands of houses, their features and prices, we can now train a supervised machine learning model to predict a new house's price based on the examples observed by the model.

Applications

- ✔ **How's the weather today?**
  - One particularly interesting problem which requires considering a lot of different parameters, is predicting weather conditions in a particular location. To make correct predictions for the weather, we need to take into account various parameters, including historical temperature data, precipitation, wind, humidity, and so on.
  - This particularly interesting and challenging problem may require developing complex supervised models that include multiple tasks. Predicting today's temperature is a regression problem, where the output labels are continuous variables. By contrast, predicting whether it is going to snow or not the next day is a binary classification problem.

Applications

- ✔ **Spam Email Detection**
  - Supervised learning can be used to classify emails as spam or legitimate. By training a model on a labeled dataset of spam and non-spam emails, it can accurately predict whether an incoming email is spam, helping filter unwanted messages.
- ✔ **Sentiment Analysis**
  - One particularly popular topic in text classification is to predict the sentiment of a piece of text, like a tweet or a product review. Sentiment analysis involves determining the sentiment or opinion expressed in text data. By training a model on labeled data that associates text with positive, negative, or neutral sentiments, it can automatically analyze large volumes of text, such as social media posts or customer reviews. This is widely used in the e-commerce industry to help companies to determine negative comments made by customers

Applications

- ✔ **Image Classification**
  - Supervised learning enables image classification tasks, where the goal is to assign a label to an image based on its content. By training a model on a dataset of labeled images, it can accurately classify new images, enabling applications like object recognition and autonomous driving.
  - **Is it a cat or a dog?**
  - is the image a car or a plane?

Applications

- ✔ **Credit Scoring**
  - In the finance industry, supervised learning is used to assess creditworthiness. By training a model on historical data that includes borrower information and their credit outcomes, it can predict the probability of default or repayment behavior for new loan applications, aiding in risk assessment.
- ✔ **Medical Diagnosis**
  - Supervised machine learning plays a crucial role in medical diagnosis. By training models on labeled medical data, such as patient symptoms and corresponding diagnoses, it can assist healthcare professionals in diagnosing diseases, identifying patterns, and recommending appropriate treatments.
- ✔ **Stock Market Prediction**
  - Supervised learning can be applied to predict stock market trends and make investment decisions. By training a model on historical stock data and relevant market indicators, it can provide insights into potential price movements, aiding investors in making informed decisions.

Benefits

Supervised machine learning offers several benefits, including:

- ✔ **Accurate predictions:** Supervised learning models can provide highly accurate predictions or classifications when trained on a diverse and representative dataset.
- ✔ **Versatility:** It can be applied to a wide range of problem domains, making it a flexible approach for various industries and applications.
- ✔ **Interpretable results:** Unlike some other machine learning approaches, supervised learning models often provide interpretable results(detailed explanations for their decisions, such as which features are most important for predicting results), allowing users to understand the reasoning behind predictions.

Limitations

However, it's important to consider the limitations:

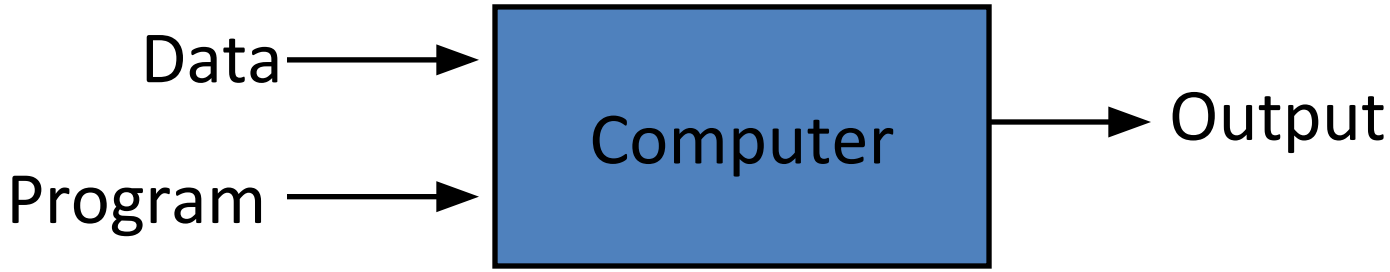
- ✔ **Dependency on labeled data:** Supervised learning relies heavily on labeled data, which can be expensive and time-consuming to collect, especially for complex problems.
- ✔ **Limited generalization:** Models trained on specific datasets may struggle to generalize well to new or unseen data that differ significantly from the training data distribution.
- ✔ **Overfitting:** If a model becomes overly complex or is trained on limited data, it may memorize the training examples instead of learning underlying patterns, leading to poor performance on unseen data.

Thank You

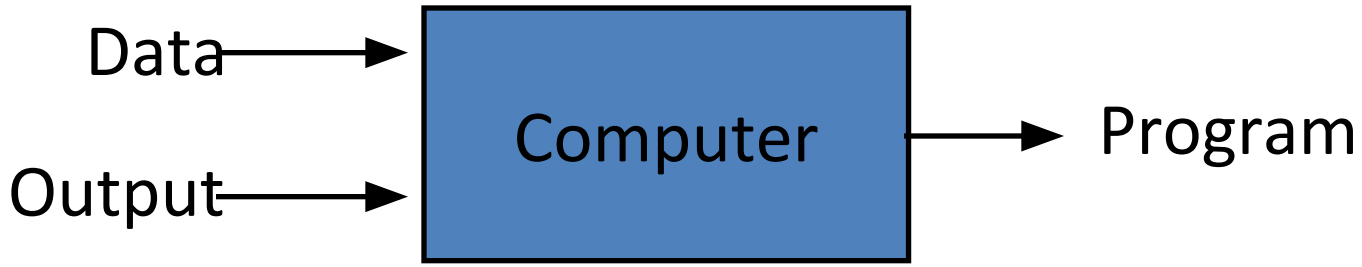
What is Machine Learning

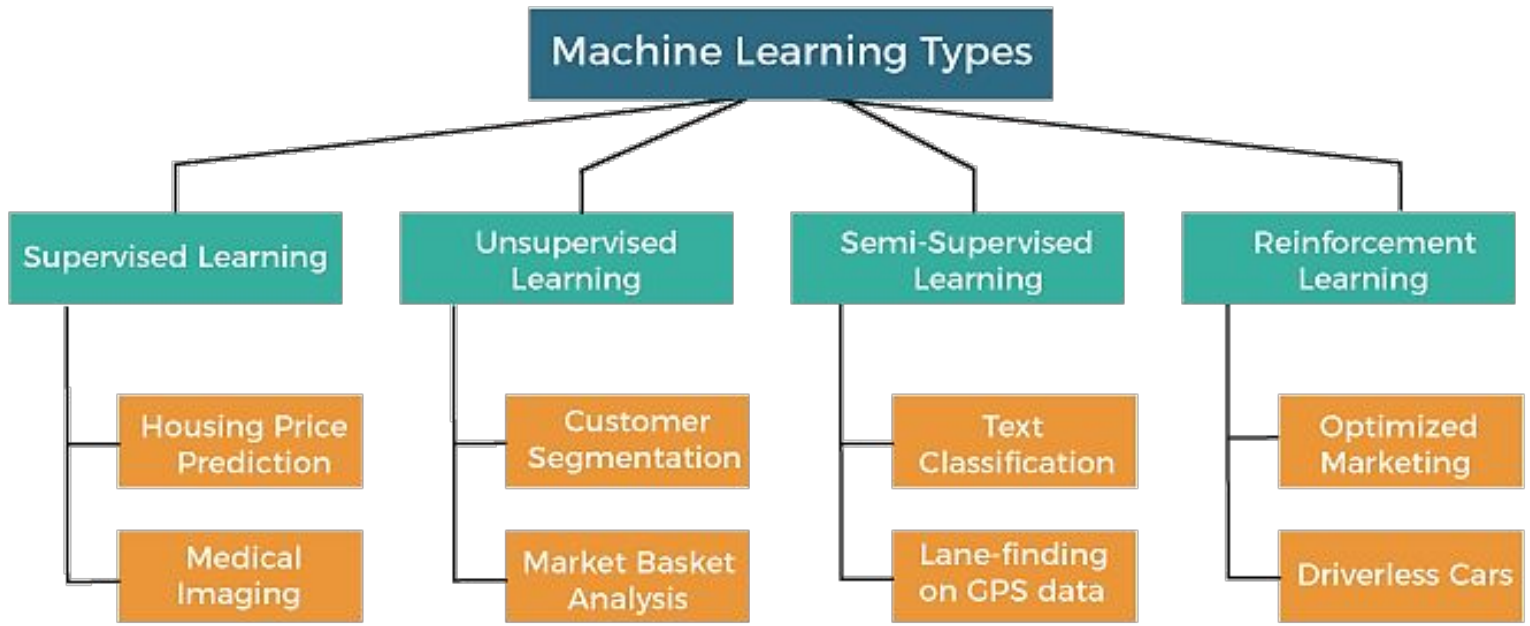
✔ "Machine Learning: Field of study that gives computers the ability to learn without being explicitly programmed." -Arthur Samuel (1959)

Traditional Programming



Machine Learning




Machine Learning Types
Supervised Learning
Unsupervised Learning
Semi-Supervised Learning
Reinforcement Learning
Housing Price Prediction
Medical Imaging
Customer Segmentation
Market Basket Analysis
Text Classification
Lane-finding on GPS data
Optimized Marketing
Driverless Cars

Frequently Asked Questions (FAQs)

- ✔ **What is the difference between feature extraction and feature selection?**
  - Feature selection involves choosing the most important features from the existing dataset. In contrast, feature extraction creates new features from the original data, typically by transforming or combining existing features.
- ✔ **Why is feature extraction used in machine learning?**
  - Feature extraction is a critical step in machine learning. It can help reduce the dimensionality of the data, improve model performance, reduce noise, and help better understand the dataset.
- ✔ **Can feature extraction improve model performance?**
  - Yes, feature extraction can greatly improve model performance. By focusing only on the most relevant features, it enables the model to process cleaner, more substantial data and deliver more accurate outcomes.
- ✔ **How is feature extraction used in image processing?**
  - In image processing, feature extraction might involve identifying distinctive characteristics like edges, textures, or colors. This helps in differentiating objects or recognizing patterns within the images.
- ✔ **What are some techniques used for feature extraction?**
  - Several techniques can be utilized for feature extraction, depending on the data and problem at hand. These could include, but are not limited to, Principal Component Analysis (PCA), Independent Component Analysis (ICA), Linear Discriminant Analysis (LDA), and Autoencoders.