Comprehensive List of Machine Learning Models

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1. Linear Regression

Definition

Linear Regression models the relationship between a dependent variable and one or more independent variables using a linear approach.

Working Algorithm

- Fits a line
- y=mx+b
- $y=mx+b$ to minimize the **Mean Squared Error (MSE)**.
- Uses gradient descent or ordinary least squares for optimization.

Use Cases

- Predicting house prices.
- Sales forecasting.

2. Polynomial Regression

Definition

Polynomial Regression extends linear regression by modeling the relationship as an nth-degree polynomial.

Working Algorithm

- Fits a curve
- y=b0+b1x+b2x2+⋯+bnxn
- Minimizes MSE using gradient descent.

Use Cases

- Modeling non-linear relationships (e.g., growth rates).
- Economic trend analysis.

3. Ridge Regression

Definition

Ridge Regression is a regularized version of linear regression that adds an L2 penalty to prevent overfitting.

Working Algorithm

- Minimizes the cost function:

$$\text{MSE} + \lambda \sum_{i=1}^{n} w_i^2$$

where λ is the regularization parameter.

Use Cases

- Handling multicollinearity in data.
- Improving model generalization.

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4. Lasso Regression

Definition

Lasso Regression adds an L1 penalty to linear regression, which can shrink some coefficients to zero, effectively performing feature selection.

Working Algorithm

- Minimizes the cost function:

$$\text{MSE} + \lambda \sum_{i=1}^{n} |w_i|$$

Use Cases

- Feature selection in high-dimensional datasets.
- Sparse data modeling.

5. Logistic Regression

Definition

Logistic Regression is used for binary classification by modeling the probability of a binary outcome.

Working Algorithm

- Uses the sigmoid function:

$$P(y=1) = \frac{1}{1+e^{-(mx+b)}}$$

- Optimizes using Maximum Likelihood Estimation (MLE).

Use Cases

- Spam detection.
- Medical diagnosis.

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6. Decision Trees

Definition

Decision Trees split data into branches based on feature values to make predictions.

Working Algorithm

- Uses metrics like **Gini Impurity** or **Information Gain** to split data.
- Stops splitting based on criteria like maximum depth or minimum samples.

Use Cases

- Customer segmentation.
- Fraud detection.

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7. Random Forest

Definition

Random Forest is an ensemble of decision trees that improves accuracy and reduces overfitting.

Working Algorithm

- Trains multiple trees on random subsets of data (bagging).
- Combines predictions through majority voting (classification) or averaging (regression).

Use Cases

- Credit scoring.
- Stock price prediction.

8. Gradient Boosting Machines (GBM)

Definition

GBM builds trees sequentially, where each tree corrects the errors of the previous one.

Working Algorithm

- Uses gradient descent to minimize loss.
- Popular implementations: XGBoost, LightGBM, CatBoost.

Use Cases

- Winning Kaggle competitions.
- Predictive modeling in finance.

9. Support Vector Machines (SVM)

Definition

SVM finds the optimal hyperplane to separate data points of different classes.

Working Algorithm

- Maximizes the margin between support vectors.
- Uses kernel functions for non-linear data.

Use Cases

- Handwritten digit recognition.
- Text classification.

10. K-Nearest Neighbors (KNN)

Definition

KNN predicts based on the similarity to the k-nearest data points.

Working Algorithm

- Computes distances (e.g., Euclidean) to find nearest neighbors.
- Uses majority voting or averaging for prediction.

Use Cases

- Recommendation systems.
- Image recognition.

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11. K-Means Clustering

Definition

K-Means groups data into k clusters based on feature similarity.

Working Algorithm

- Initializes k centroids and assigns points to the nearest centroid.
- Repeats until convergence.

Use Cases

- Customer segmentation.
- Image compression.

12. Hierarchical Clustering

Definition

Hierarchical Clustering builds a tree of clusters (dendrogram) without specifying the number of clusters.

Working Algorithm

- Agglomerative: Starts with each point as a cluster and merges the closest pairs.
- Divisive: Starts with one cluster and splits recursively.

Use Cases

- Gene sequence analysis.
- Social network analysis.

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

Definition

DBSCAN groups data points based on density and identifies outliers as noise.

Working Algorithm

- Defines clusters as dense regions separated by low-density areas.
- Uses two parameters: **eps** (radius) and **min_samples**.

Use Cases

- Anomaly detection.
- Geographic data analysis.

14. Principal Component Analysis (PCA)

Definition

PCA reduces dimensionality by transforming data into principal components.

Working Algorithm

- Computes eigenvectors and eigenvalues of the covariance matrix.
- Projects data onto the top k eigenvectors.

Use Cases

- Data visualization.
- Noise reduction.

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15. Neural Networks

Definition

Neural Networks are deep learning models inspired by the human brain.

Working Algorithm

- Consists of layers of neurons with activation functions.
- Trained using backpropagation and gradient descent.

Use Cases

- Image and speech recognition.
- Natural language processing.

16. Naive Bayes

Definition

Naive Bayes is a probabilistic classifier based on Bayes' theorem, assuming feature independence.

Working Algorithm

- Computes posterior probabilities:

$$P(y|X) = \frac{P(X|y)P(y)}{P(X)}$$

Use Cases

- Spam filtering.
- Sentiment analysis.

17. Reinforcement Learning (Q-Learning)

Definition

Reinforcement Learning involves an agent learning to make decisions by interacting with an environment.

Working Algorithm

- Uses a Q-table to store expected rewards for state-action pairs.
- Updates Q-values using the Bellman equation.

Use Cases

- Game playing (e.g., AlphaGo).
- Robotics.

18. Gaussian Mixture Models (GMM)

Definition

GMM is a probabilistic model that assumes data is generated from a mixture of Gaussian distributions.

Working Algorithm

- Uses the Expectation-Maximization (EM) algorithm to estimate parameters.
- Assigns probabilities to data points for each cluster.

Use Cases

- Image segmentation.
- Anomaly detection.

19. Elastic Net Regression

Definition

Elastic Net Regression is a regularized regression method that combines the **L1 penalty (Lasso)** and **L2 penalty (Ridge)**. It is useful when dealing with datasets that have highly correlated features or when the number of features is greater than the number of samples.

Working Algorithm

- The cost function for Elastic Net is:

$$\text{MSE} + \lambda_1 \sum_{i=1}^{n} |w_i| + \lambda_2 \sum_{i=1}^{n} w_i^2$$

  where:
  - λ_1 controls the L1 penalty (sparsity).
  - λ_2 controls the L2 penalty (ridge regularization).
- The model is optimized using coordinate descent or gradient descent.

Use Cases

- Feature selection in high-dimensional datasets (e.g., genomics).
- Predicting outcomes in datasets with multicollinearity (e.g., financial data).
- Regularization in cases where both Ridge and Lasso are needed.

20. Isolation Forest

Definition

Isolation Forest is an **unsupervised anomaly detection algorithm** that isolates anomalies instead of profiling normal data points. It works on the principle that anomalies are few and different, making them easier to isolate.

Working Algorithm

- The algorithm builds an ensemble of isolation trees (iTrees).
- Each tree randomly selects a feature and splits the data into two partitions.
- Anomalies are identified as points that require fewer splits to be isolated.
- The anomaly score is calculated based on the average path length from the root to the leaf node.

Use Cases

- Fraud detection in financial transactions.
- Network intrusion detection.
- Identifying defective products in manufacturing.

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21. Long Short-Term Memory (LSTM)

Definition

LSTM is a type of **Recurrent Neural Network (RNN)** designed to model sequential data by capturing long-term dependencies. It overcomes the vanishing gradient problem in traditional RNNs.

Working Algorithm

- LSTMs use a memory cell and three gates (input, forget, and output) to control information flow.
  - **Input Gate**: Decides what new information to store.
  - **Forget Gate**: Decides what information to discard.
  - **Output Gate**: Decides what information to output.
- The memory cell retains information over long periods, making LSTMs effective for sequential data.

Use Cases

- Time-series forecasting (e.g., stock prices, weather).
- Natural language processing (e.g., text generation, machine translation).
- Speech recognition and audio analysis.
- Anomaly detection in sequential data (e.g., sensor data).