Machine Learning Techniques

- **Support Vector Machines (SVM)** – A classification algorithm that finds the optimal hyperplane to separate data into different classes.
  Application: Can classify different fish species based on their unique acoustic patterns.
- **K-Nearest Neighbors (KNN)** – A simple, non-parametric method that classifies data by assigning the label of the 'k' nearest data points.
  Application: Could be used for fish species classification by comparing new acoustic samples with known examples.
- **Hidden Markov Models (HMM)** – A probabilistic model used to analyze sequences where the system being modeled is assumed to be a Markov process with hidden states.
  Application: Useful for detecting sequential patterns in fish vocalizations or movement-related sounds.
- **Gaussian Mixture Models (GMM)** – A clustering algorithm that models data as a mixture of multiple Gaussian distributions.
  Application: Can be used to group fish species based on shared acoustic characteristics.
- **Random Forest (RF)** is a supervised machine learning method that creates a set of classification trees obtained by the random selection of a group of variables from the variable space and a bootstrap procedure that recurrently selects a fraction of the sample space to fit the model.

Deep Learning Techniques

- **Convolutional Neural Networks (CNNs)** – A neural network primarily used for analyzing images and spatial data, such as spectrograms of audio signals.
  Application: Can classify fish species using spectrogram representations of underwater recordings.
- **Recurrent Neural Networks (RNNs)** – A type of neural network designed for sequential data processing, such as time-series analysis.
  Application: Can process continuous underwater sound recordings and detect species-specific patterns.
- **Long Short-Term Memory (LSTMs)** – An improved version of RNNs that can remember long-term dependencies and mitigate vanishing gradient issues.
  Application: Can be useful for tracking recurring fish vocalizations over time.
- **Deep Belief Networks (DBNs)** – A stack of neural layers (Restricted Boltzmann Machines) that learn feature hierarchies in an unsupervised manner.
  Application: Can learn characteristic patterns of fish calls from large datasets without explicit labels.

- **Autoencoders** – Neural networks that compress input data into a lower-dimensional representation and reconstruct it, useful for denoising.
  Application: Can be used to remove background noise from underwater recordings before analysis.
- **Residual Networks (ResNet)** – A deep CNN architecture that allows very deep networks without performance degradation using shortcut connections.
  Application: Used for efficient and scalable species classification.

Feature Extraction & Signal Processing Techniques

- **Mel-Frequency Cepstral Coefficients (MFCCs)** – A widely used audio feature extraction technique that models human auditory perception of sound.
  Application: Can help identify fish species based on their unique frequency characteristics.
- **Short-Time Fourier Transform (STFT)** – A method that represents a signal in both time and frequency domains, producing a spectrogram.
  Application: Can visualize fish calls and provide input for CNN-based classification.
- **Gammatone Cepstral Coefficients (GTCCs)** – Similar to MFCCs but based on gammatone filter banks, which mimic human auditory processing.
  Application: Can enhance fish call detection in noisy environments.
- **Greenwood Function Cepstral Coefficients (GFCCs)** – A bioacoustics-based feature extraction method, useful for analyzing animal and bird calls.
  Application: Could be useful for fish vocalization analysis, leveraging known bioacoustic techniques.
- **Wavelet Transform (WT)** – A technique for analyzing non-stationary signals by breaking them into different frequency components.
  Application: Can analyze fish calls that vary over time.
- **Spectrograms** – A visual representation of an audio signal's frequency content over time.
  Application: Can be processed using image-based AI models to classify different fish species.
- **Zero-Crossing Rate (ZCR)** – Measures how often a signal changes sign, often used in speech and bioacoustics.
  Application: Can differentiate species based on variations in vocalization patterns.
- **Envelope Modulation Spectrum (EMS)** – Captures amplitude variations across different frequencies.
  Application: Helps in distinguishing between different fish vocalization patterns.
- **Histogram of Oriented Gradients (HOG)** – An image feature descriptor that captures edge and texture information.
  Application: Can be used on spectrograms to enhance species classification accuracy.
- **Local Binary Patterns (LBP) & Local Ternary Patterns (LTP)** – Techniques used for texture analysis in images.

Application: Can be applied to spectrograms for better feature extraction in fish identification.

AI Training & Optimization Techniques

- **Principal Component Analysis (PCA)** – A dimensionality reduction technique that extracts the most important features from data.
  Application: Can optimize fish sound classification models by reducing redundant information.
- **Data Augmentation** – A technique to artificially expand datasets by modifying existing data samples (e.g., time-stretching, pitch-shifting).
  Application: Can be used to generate more fish vocalization samples to improve AI training.
- **Transfer Learning** – A method where a pre-trained AI model is fine-tuned for a new task.
  Application: Can adapt existing bioacoustic models (e.g., bird song recognition) for fish species identification.
- **Few-Shot Learning** – A training approach that enables AI models to recognize new categories with very few examples.
  Application: Useful for identifying rare fish species with limited data.
- **Mixup Training** – A method that combines multiple training samples to improve classification performance in overlapping sound environments.
  Application: Helps in distinguishing overlapping fish calls.
- **Sliding Window Prediction** – A method where a model processes short overlapping segments of an audio file rather than the entire recording.
  Application: Helps localize fish calls within a long underwater recording.

Evaluation Metrics & Performance Analysis

$$\text{Accuracy} = \frac{\text{Correct predictions}}{\text{All predictions}}$$

$$\text{Accuracy} = \frac{TP + TN}{TP + TN + FP + FN}$$

$$\text{Recall} = \frac{\text{True Positives}}{\text{True Positives} + \text{False Negatives}}$$

- [**Precision, Recall & F1-Score**]() – Metrics used to evaluate classification performance, especially for imbalanced datasets.
  Application: Can help assess how well different fish species are distinguished
- **Recall**- a metric that measures how often a machine learning model correctly identifies positive instances (true positives) from all the actual positive samples in the dataset.
- **Precision-** a metric that measures how often a machine learning model correctly predicts the positive class. You can calculate precision by dividing the number of correct positive predictions (true positives) by the total number of instances the model predicted as positive (both true and false positives).
- **Confusion Matrix** – A table that summarizes classification performance, showing true/false positives and negatives.
  Application: Useful for analyzing misclassified fish sounds.
- **Receiver Operating Characteristic (ROC) & Area Under the Curve (AUC-ROC)** – Measures a classifier's ability to distinguish between classes.
  Application: Can help determine the reliability of a fish species classifier.
- **Matthews Correlation Coefficient (MCC)** – A more balanced evaluation metric, especially useful for imbalanced datasets.
  Application: Can be used when some fish species are more frequently recorded than others.
- **False Positive Rate (FPR)** – Measures the proportion of false detections, critical for reducing background noise interference.
  Application: Important for avoiding incorrect fish detections.

Optimization & Heuristic Algorithms

Grey Wolf Optimization (GWO) – A nature-inspired optimization algorithm used for training neural networks.
Application: Can optimize model parameters for fish species classification.

Whale Optimization Algorithm (WOA) – A bio-inspired optimization algorithm used in AI model training.
Application: Can fine-tune machine learning models for underwater sound classification.

Dragonfly Algorithm (DA) – A meta-heuristic optimization technique that improves AI model efficiency.
Application: Can help improve fish sound classification accuracy by optimizing feature selection.

Salp Swarm Algorithm (SSA) – An optimization technique used for training machine learning models.
Application: Can speed up AI model training for fish sound analysis.

Ant Lion Optimization (ALO) – A bio-inspired algorithm for improving AI models.
Application: Can help refine deep learning models used in fish species classification.