Learning Process in Machine Learning Models

From Observation to Optimization

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Outline

Understanding the Learning Process

Goal

To understand how machine learning models learn from data by minimizing an error between the predicted and expected outputs.

Key steps

1. Feed data forward (Observation)
2. Compute the loss (Error measurement)
3. Optimize parameters (Back-propagation or similar adjustment)
4. Repeat until convergence

Feed Forward Phase

Observation

Each input $x^{(i)}$ passes through the model to produce a prediction $\hat{y}^{(i)}$.

- In **KNN**, distances between data points are computed.
- In **Decision Tree**, splits are made according to feature thresholds.
- In **Random Forest**, multiple trees vote for the final prediction.
- In **SVM**, data points are projected into a hyperplane.

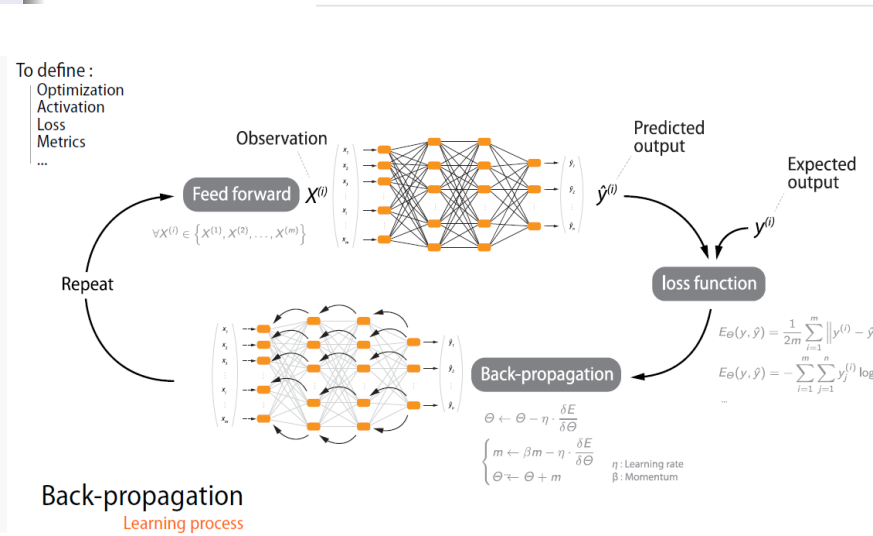

Figure: Feed forward: from input $x^{(i)}$ to predicted output $\hat{y}^{(i)}$

Loss Function

Definition

The loss function measures the difference between the predicted output $\hat{y}$ and the true output y.

$$E(\theta) = \frac{1}{2m} \sum_{i=1}^{m} (y^{(i)} - \hat{y}^{(i)})^2$$

- For classification: Cross-entropy loss
- For regression: Mean Squared Error (MSE)

Goal

Minimize the loss to improve model performance.

Optimization and Back-propagation

Concept

Optimization updates the model parameters to reduce the loss.

$$\theta \leftarrow \theta - \eta \frac{\partial E}{\partial \theta}$$

$$m \leftarrow \beta m - \eta \frac{\partial E}{\partial \theta}$$

$$\theta \leftarrow \theta + m$$

- $\eta =$ Learning rate
- $\beta =$ Momentum (helps smooth updates)

For traditional ML

- **KNN:** No optimization, uses distance-based decision.
- **Decision Tree / Random Forest:** Optimization through information gain or Gini index.
- **SVM:** Optimization via convex quadratic programming.

Repeat and Evaluate

Iteration

The process is repeated for many epochs or until convergence:

1. Forward pass
2. Compute loss
3. Update parameters

Evaluation Metrics

- Accuracy
- Precision, Recall, F1-score
- ROC-AUC for classification
- RMSE, MAE for regression

Goal

Achieve the best generalization on unseen data.

Conclusion

Summary

- All ML models follow a learning loop:

$$\text{Feed forward} \rightarrow \text{Loss} \rightarrow \text{Optimization} \rightarrow \text{Repeat}$$

- Differences lie in how they model the relationship between inputs and outputs.

Key Takeaway

Learning is an iterative optimization of parameters to reduce the gap between prediction and truth.