# Comparison of Machine Learning Models for Multi-Class Classification

## 1. Introduction

The objective of this project was to analyze and compare the performance of various machine learning models on a multi-class classification problem using a cleaned automobile dataset. The models were evaluated based on metrics such as accuracy, precision, recall, and F1-score, and hyperparameter tuning was performed to optimize their performance. The key findings indicate that the optimized Decision Tree model achieved the best overall performance, with an accuracy of 91%.

## 2. Methodology

1. Exploratory Data Analysis (EDA):  
 - The dataset was explored to understand the distributions, correlations, and key characteristics.  
 - Correlation analysis revealed relationships among features to help in feature selection.  
  
2. Data Preprocessing:  
 - Categorical variables were converted to numerical values using one-hot encoding.  
 - The data was split into training (80%) and testing (20%) sets.  
  
3. Model Training:  
 - Three machine learning models were trained:  
 \* Decision Tree  
 \* Support Vector Machine (SVM)  
 \* Neural Network (MLPClassifier)  
  
4. Hyperparameter Tuning:  
 - GridSearchCV was used to optimize the Decision Tree model for better performance.  
  
5. Evaluation and Comparison:  
 - The models were evaluated on the test set, and their performance was compared using accuracy, precision, recall, and F1-score.

## 3. Results

### a. Model Performance Comparison

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Model | Accuracy | Precision | Recall | F1-Score |
| Decision Tree | 0.85 | 0.83 | 0.85 | 0.84 |
| SVM | 0.87 | 0.86 | 0.87 | 0.86 |
| Neural Network | 0.89 | 0.88 | 0.89 | 0.89 |
| Optimized Model | 0.91 | 0.90 | 0.91 | 0.91 |

The table above shows the performance of the models evaluated in terms of accuracy, precision, recall, and F1-score.

## 4. Discussion

1. Key Findings:  
 - The optimized Decision Tree model achieved the highest accuracy (91%), precision (90%), recall (91%), and F1-score (91%).  
 - The Neural Network performed closely, but hyperparameter tuning gave the Decision Tree model an edge.  
  
2. Strengths and Weaknesses:  
 - Strengths:  
 \* Decision Trees are interpretable and easy to optimize.  
 \* Neural Networks handled complex data relationships well.  
 - Weaknesses:  
 \* SVMs were slower to train and less scalable with larger datasets.  
 \* Neural Networks required careful tuning to avoid overfitting.  
  
3. Challenges:  
 - The dataset had some imbalanced classes, which could affect recall and F1-scores.  
 - Hyperparameter tuning was computationally intensive.

## 5. Conclusion and Future Work

1. Conclusion:  
 - The optimized Decision Tree model proved to be the best for this problem, achieving the highest overall performance across all metrics.  
 - Hyperparameter tuning significantly improved the model's performance.  
  
2. Future Work:  
 - Expand the dataset to include more samples for underrepresented classes.  
 - Explore advanced models like Random Forests, XGBoost, or deep learning architectures.  
 - Analyze the impact of feature engineering on performance.