**ALY 6020**

**Report**

**Predictive Analytics**

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**Introduction**

This report provides an analysis of automobile fuel efficiency (measured as MPG - Miles Per Gallon) using linear regression modeling. The objective is to identify the key factors influencing MPG and develop a predictive model. Furthermore, the model is optimized to improve performance by selecting significant features. This process involves exploratory data analysis (EDA), building a linear regression model, evaluating its performance, and optimizing it using feature selection techniques.

**Analysis**

**Data Cleaning**

To ensure the dataset is clean and ready for analysis:

* **Horsepower** was converted to numeric, and any invalid values were treated as missing. This step was essential to ensure the data type was compatible with the regression model, as numerical computations cannot handle non-numeric data.
* Missing values in numerical columns were filled with the mean of their respective columns. This avoided errors during model training and ensured no data was lost.
* **Cylinders** and **US Made** were converted to categorical variables to represent their grouped nature effectively. This helped the model distinguish between categories rather than treating them as continuous variables.

**Exploratory Data Analysis (EDA)**

EDA was conducted to explore relationships between features and the target variable (MPG):

1. **Distribution of MPG**:
   * MPG values showed a slightly skewed distribution, with most values concentrated between 15 and 30 MPG.
   * This indicates that most vehicles in the dataset have average fuel efficiency, with fewer extremely high or low values.

A graph of a distribution of fuel

Description automatically generated

1. **Pairplot**:
   * The pairplot revealed:
     + **Negative correlations**:
       - **Displacement**: Larger engine displacement tends to reduce MPG, likely because bigger engines consume more fuel. This highlights the importance of designing smaller, more efficient engines to improve fuel efficiency.
       - **Horsepower**: Higher horsepower is associated with lower MPG, as more powerful engines are generally less fuel-efficient. Manufacturers should aim for a balance between performance and efficiency.
       - **Weight**: Heavier vehicles have lower MPG, as they require more energy to move. Reducing vehicle weight through materials and design can significantly enhance MPG.
     + **Positive correlation**:
       - **Acceleration**: Vehicles with higher acceleration tend to have slightly better MPG, possibly because efficient acceleration reflects advanced engine technology. This suggests that integrating modern technologies can improve overall efficiency.

A collage of blue dots

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1. **Correlation Heatmap**:
   * **Weight (-0.83)**: This strong negative correlation means heavier vehicles significantly reduce MPG, indicating weight is a critical factor in fuel efficiency. Lightweight materials and design optimizations are crucial for better MPG.
   * **Displacement (-0.80)**: Engine size has a major impact, with larger engines consuming more fuel per mile. Downsizing engines or improving engine technology can address this issue.
   * **Horsepower (-0.77)**: More powerful engines reduce fuel efficiency, showing a trade-off between performance and economy. Manufacturers should consider engine tuning and hybrid technologies to mitigate this trade-off.
   * **Acceleration (0.42)**: Although weak, this positive correlation suggests vehicles with better acceleration may have more modern, fuel-efficient designs. This indicates the potential benefits of combining performance with efficiency.

A screenshot of a graph

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**Building the Linear Regression Model**

1. **Feature Preparation**:
   * Features such as Cylinders, Displacement, Horsepower, Weight, Acceleration, Model Year, and US Made were selected.
   * Dummy variables were created for categorical features to ensure proper interpretation by the model.
2. **Model Training**:
   * The data was split into training and testing sets (80%-20% split).
   * A linear regression model was trained using the training set.
3. **Model Evaluation**:
   * The model achieved:
     + **Mean Squared Error (MSE)**: 7.91
     + **R-squared Score**: 0.85
   * A scatter plot of actual vs. predicted MPG values showed that predictions aligned well with the actual values.

A graph with blue dots and red line

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**Model Optimization**

1. **Feature Selection**:
   * Using SelectKBest with f\_regression, each feature was ranked based on its contribution to predicting MPG.
   * Features with a p-value < 0.05 were retained. This step reduced noise and focused the model on the most impactful features.
2. **Retraining the Model**:
   * The optimized model was retrained using only the significant features. This simplified the model and reduced overfitting.
3. **Optimized Model Evaluation**:
   * The optimized model achieved:
     + **Optimized Mean Squared Error (MSE)**: 7.88
     + **Optimized R-squared Score**: 0.85
   * The results show slight improvement in performance after optimization, confirming that the selected features were highly relevant.

**Results**

The analysis revealed that Weight, Displacement, and Horsepower are the most significant predictors of MPG. The linear regression model provided a strong predictive capability, with an R-squared score of 0.85. After optimization, the model retained similar performance while relying on fewer features.

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**Conclusion**

This report demonstrates the application of linear regression to predict automobile fuel efficiency and highlights the importance of feature selection for model optimization. The results confirm that factors like Weight, Displacement, and Horsepower significantly impact MPG.

* **Weight**: Heavier vehicles consume more fuel, making this the strongest factor in reducing MPG. Reducing weight through innovative materials and efficient designs should be a priority for manufacturers.
* **Displacement**: Larger engines negatively affect fuel efficiency, emphasizing the need for smaller, more efficient engines or advanced technologies like turbocharging.
* **Horsepower**: High performance comes at a cost to MPG. Balancing power with fuel efficiency is crucial for appealing to customers seeking both performance and economy.
* **Acceleration**: While only weakly positive, better acceleration suggests modern, efficient engine designs. Investing in advanced technologies can enhance both performance and MPG.

**References**

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