DSC680-Project1

September 27, 2025

[1]:
```python
# 1) Setup
import os, zipfile
from pathlib import Path
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
from sklearn.model_selection import train_test_split
from sklearn.compose import ColumnTransformer
from sklearn.pipeline import Pipeline
from sklearn.impute import SimpleImputer
from sklearn.preprocessing import OneHotEncoder, StandardScaler
from sklearn.metrics import mean_squared_error, mean_absolute_error, r2_score
from sklearn.linear_model import LinearRegression, RidgeCV
from sklearn.ensemble import RandomForestRegressor, GradientBoostingRegressor
import joblib

import warnings
warnings.filterwarnings("ignore")
from IPython.core.display import display, HTML
display(HTML("<style>.jp-OutputArea { overflow: visible !important; }</style>"))

dataset_path = r"C:
↪\Users\amyha\OneDrive\Documents\DSC680\car_insurance_premium_dataset.csv"
df = pd.read_csv(dataset_path)
```

```
<IPython.core.display.HTML object>
```

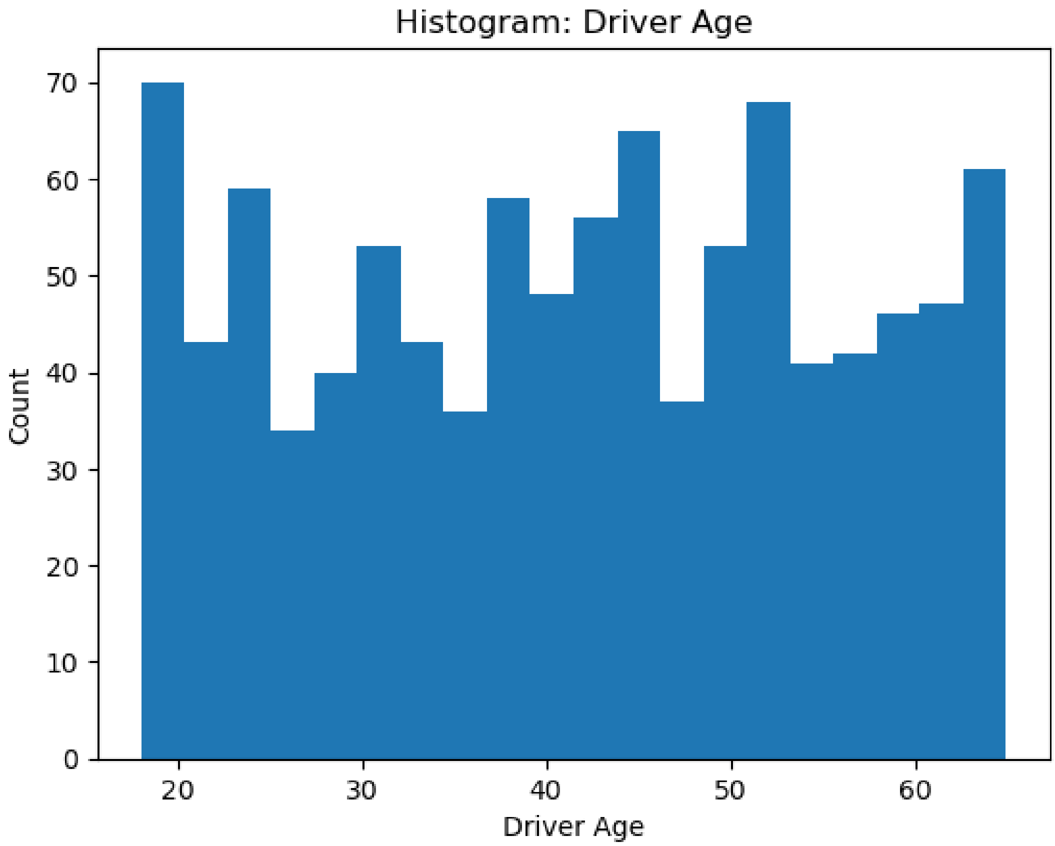
[2]:
```python
# 2) Summary statistics
display(df.describe(include='all'))
```

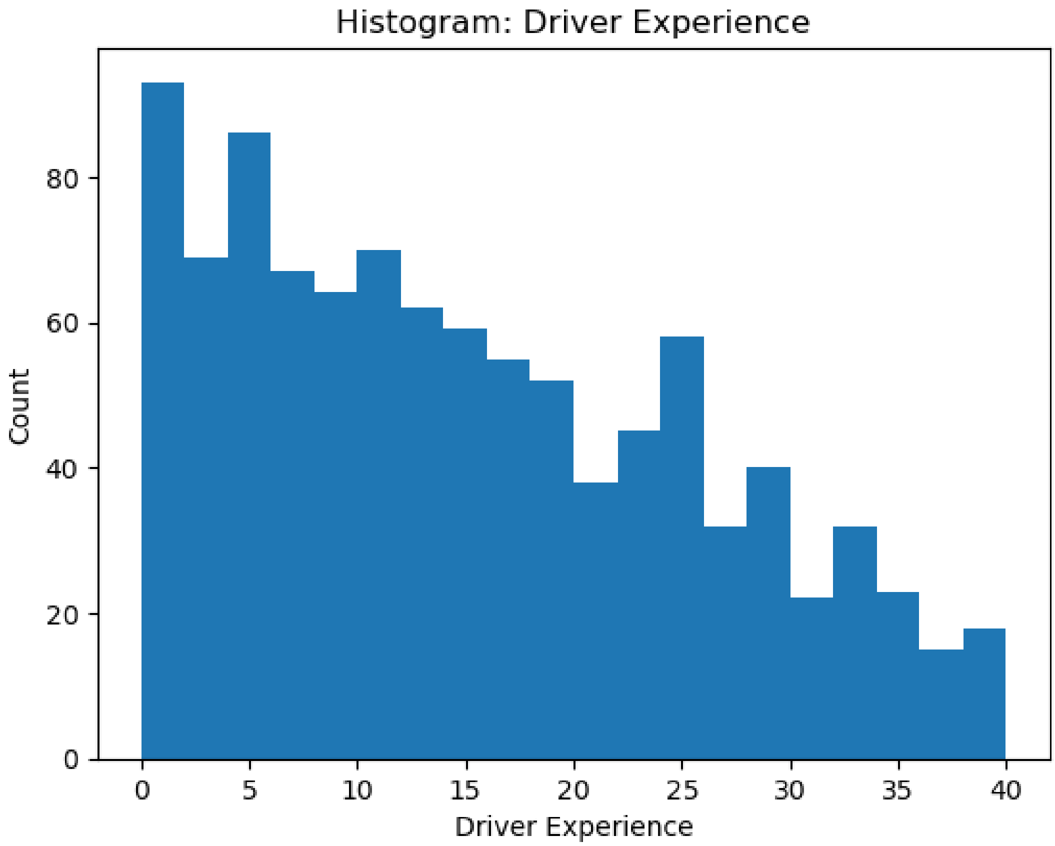
```
        Driver Age  Driver Experience  Previous Accidents  \
count  1000.000000        1000.000000           1000.0000
mean     41.575000          14.759000              2.5680
std      13.765677          10.544292              1.6989
min      18.000000           0.000000              0.0000
25%      30.000000           6.000000              1.0000
50%      42.000000          13.000000              3.0000
75%      53.000000          23.000000              4.0000
```

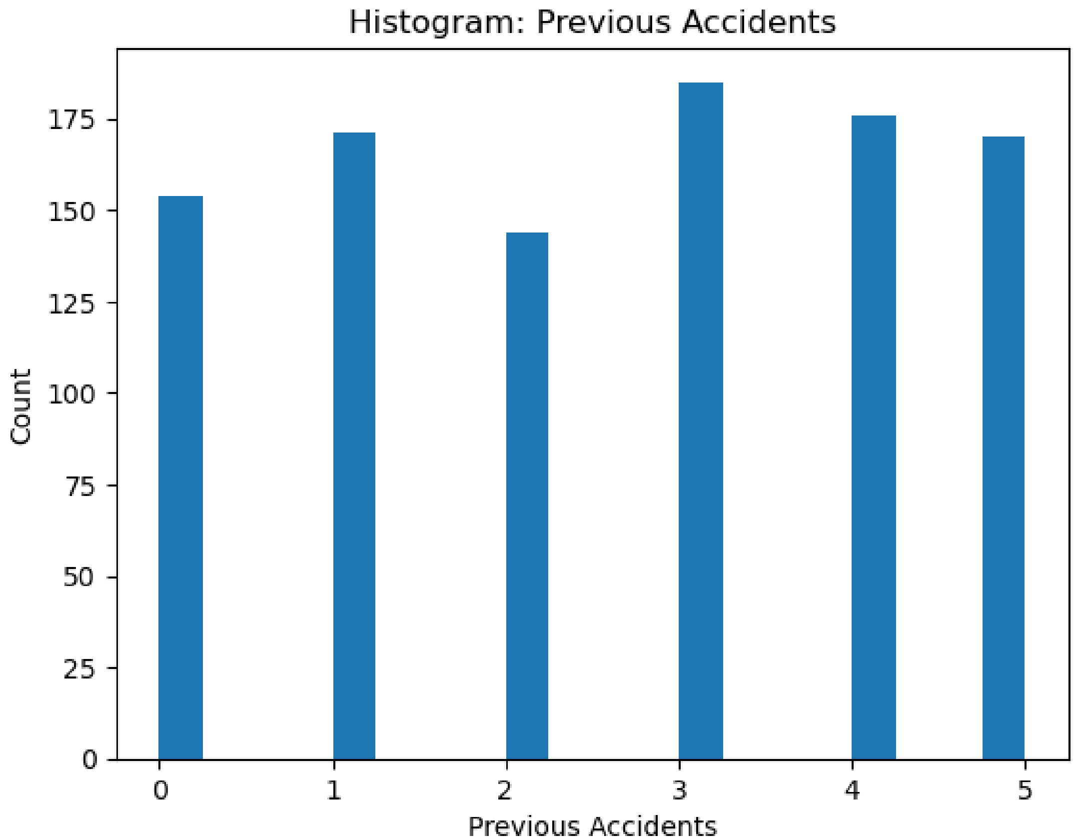
```
max      65.000000          40.000000            5.0000

       Annual Mileage (x1000 km)  Car Manufacturing Year      Car Age  \
count                 1000.000000             1000.000000  1000.000000
mean                    17.933000             2007.637000    17.363000
std                      4.410665               10.363331    10.363331
min                     11.000000             1990.000000     0.000000
25%                     14.000000             1999.000000     8.000000
50%                     18.000000             2008.000000    17.000000
75%                     22.000000             2017.000000    26.000000
max                     25.000000             2025.000000    35.000000

       Insurance Premium ($)
count            1000.000000
mean              493.742250
std                 5.909689
min               477.050000
25%               489.487500
50%               493.950000
75%               498.312500
max               508.150000
```

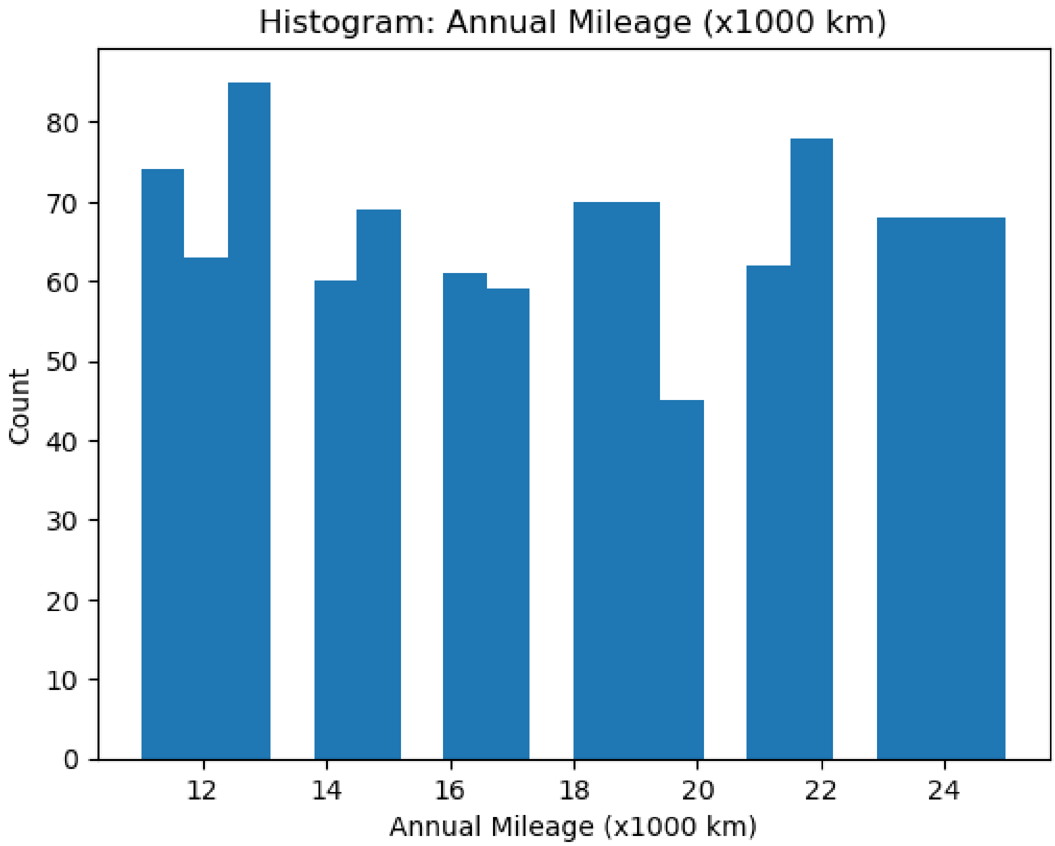
[3]:

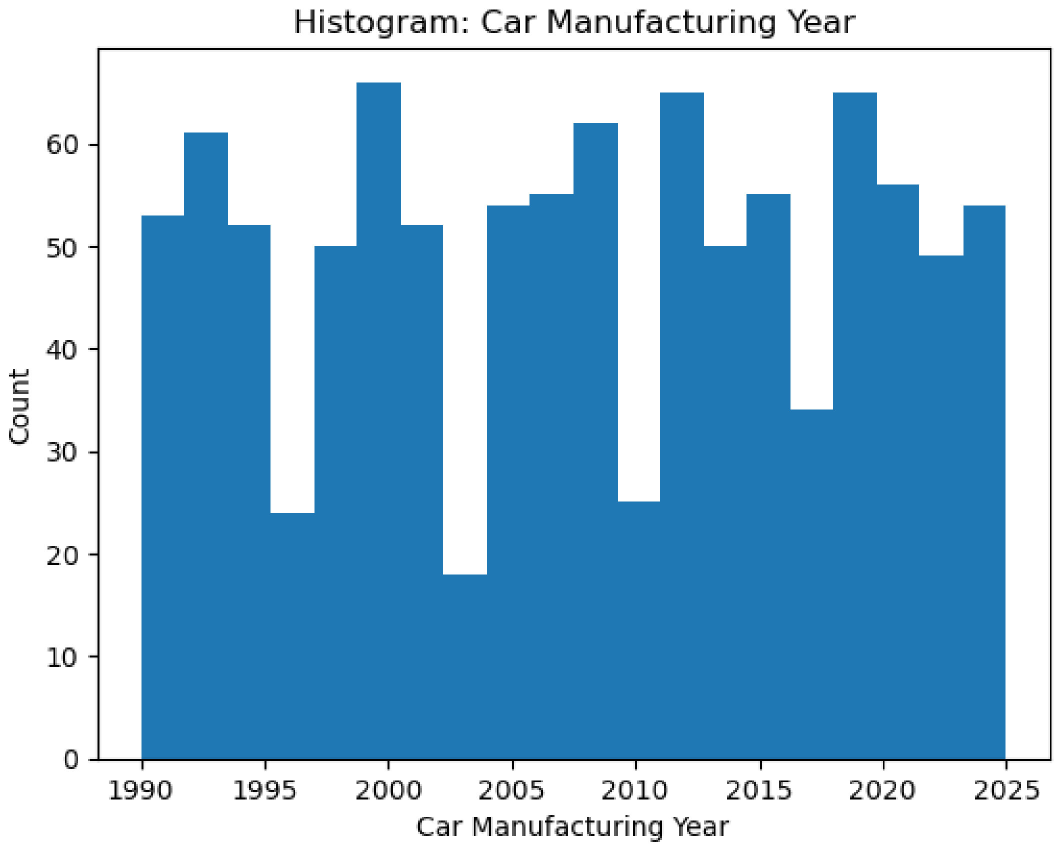
```
# 3) Distributions - one chart per column
numeric_cols = [c for c in df.columns if pd.api.types.is_numeric_dtype(df[c])]
for col in numeric_cols:
    plt.figure()
    df[col].plot(kind='hist', bins=20, title=f'Histogram: {col}')
    plt.xlabel(col)
    plt.ylabel('Count')
    plt.show()
```

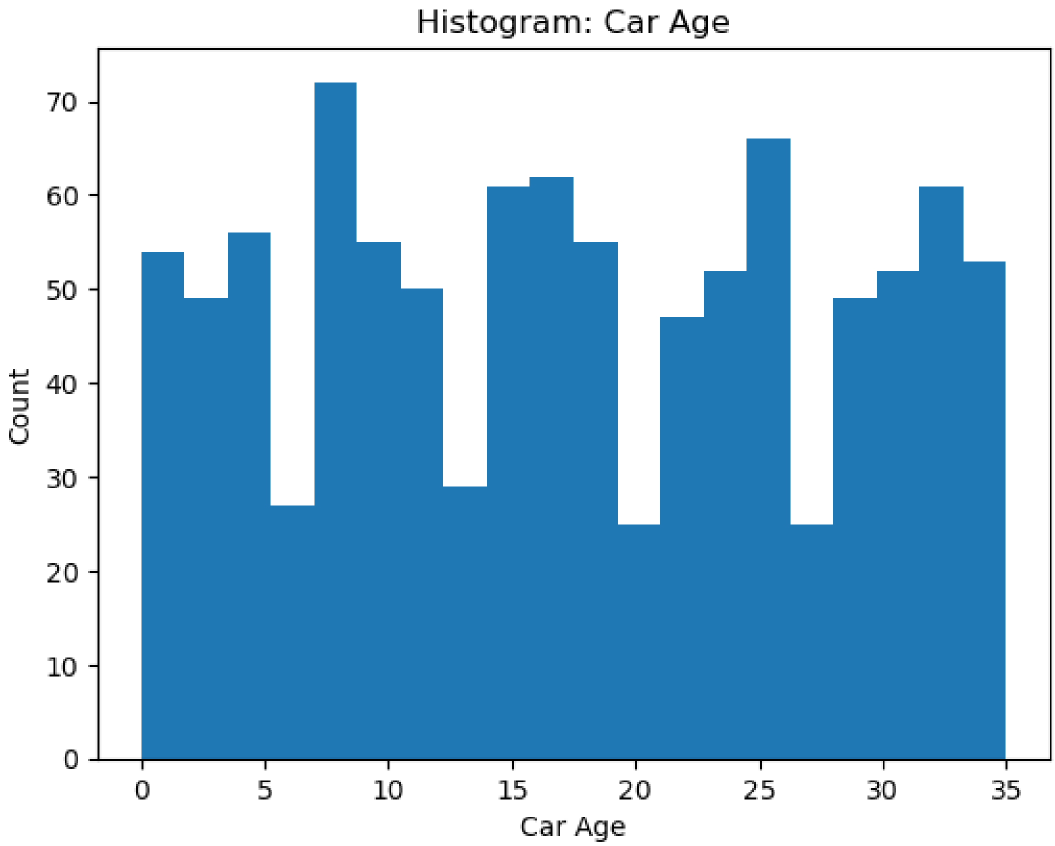

Histogram: Driver Age
70
60
50
40
30
20
10
0
Count
20
30
40
50
60
Driver Age

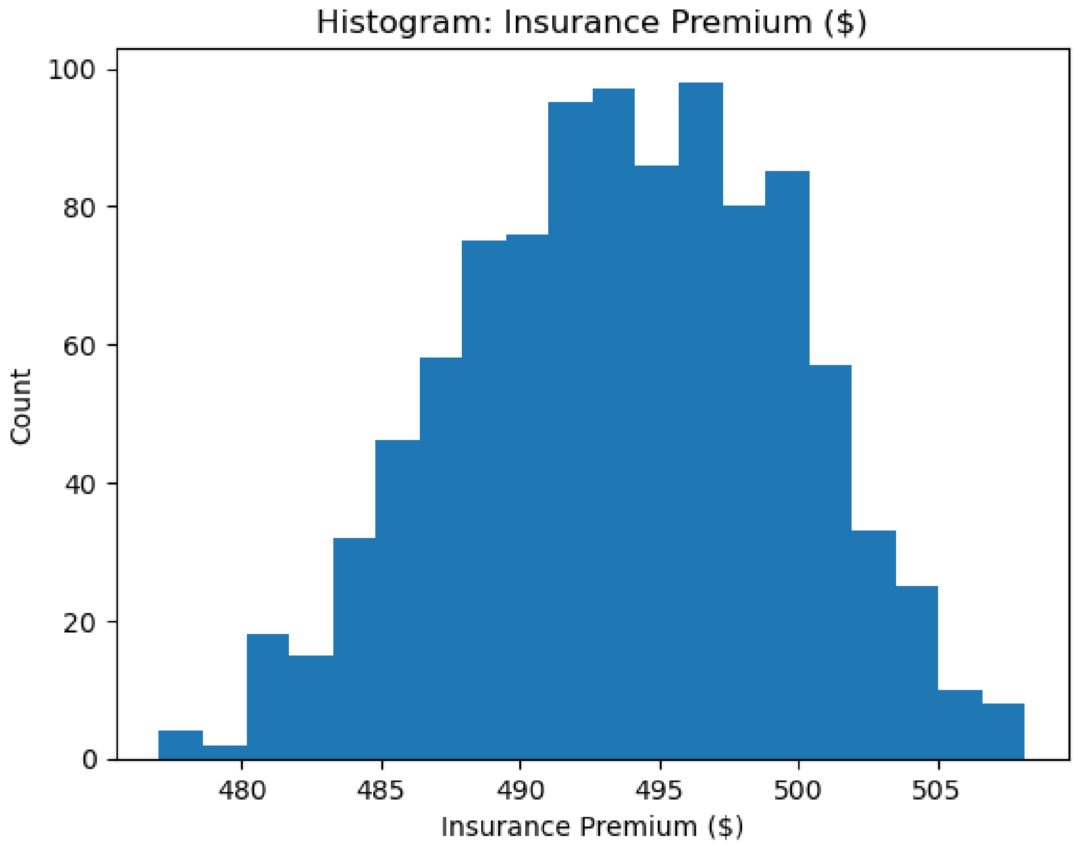

Histogram: Driver Experience
80
60
40
20
0
Count
0
5
10
15
20
25
30
35
40
Driver Experience


Histogram: Previous Accidents
Count
0
25
50
75
100
125
150
175
0
1
2
3
4
5
Previous Accidents

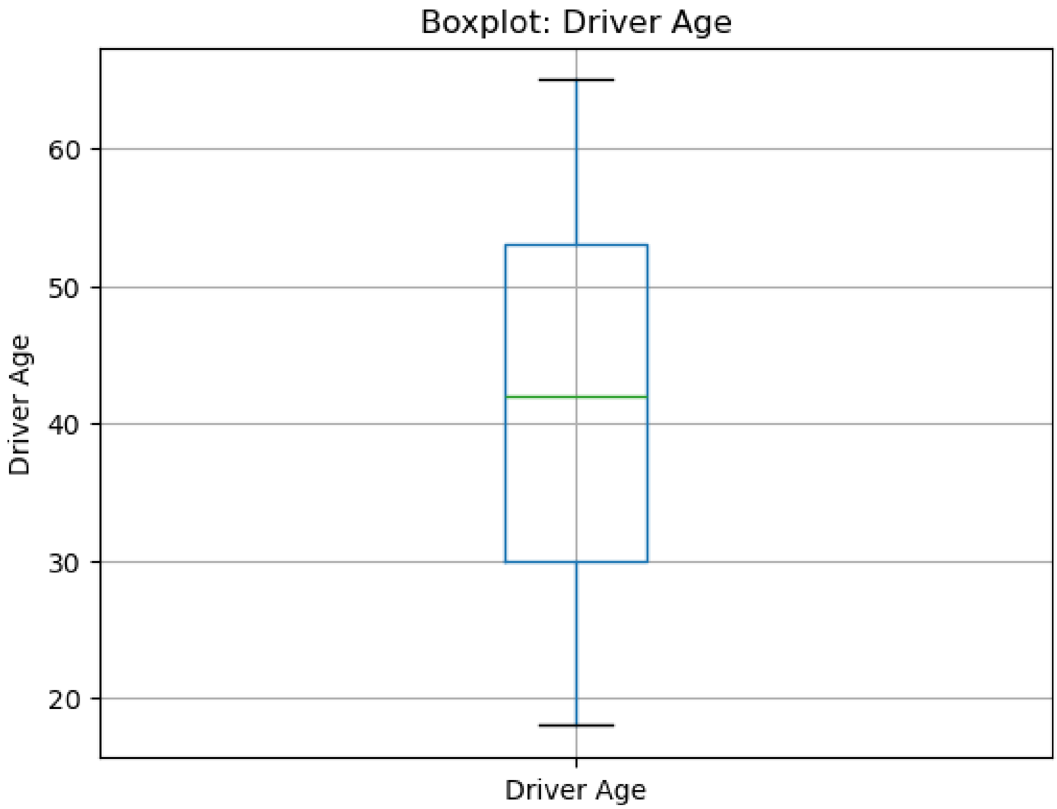

Histogram: Annual Mileage (x1000 km)
Count
0
10
20
30
40
50
60
70
80
12
14
16
18
20
22
24
Annual Mileage (x1000 km)

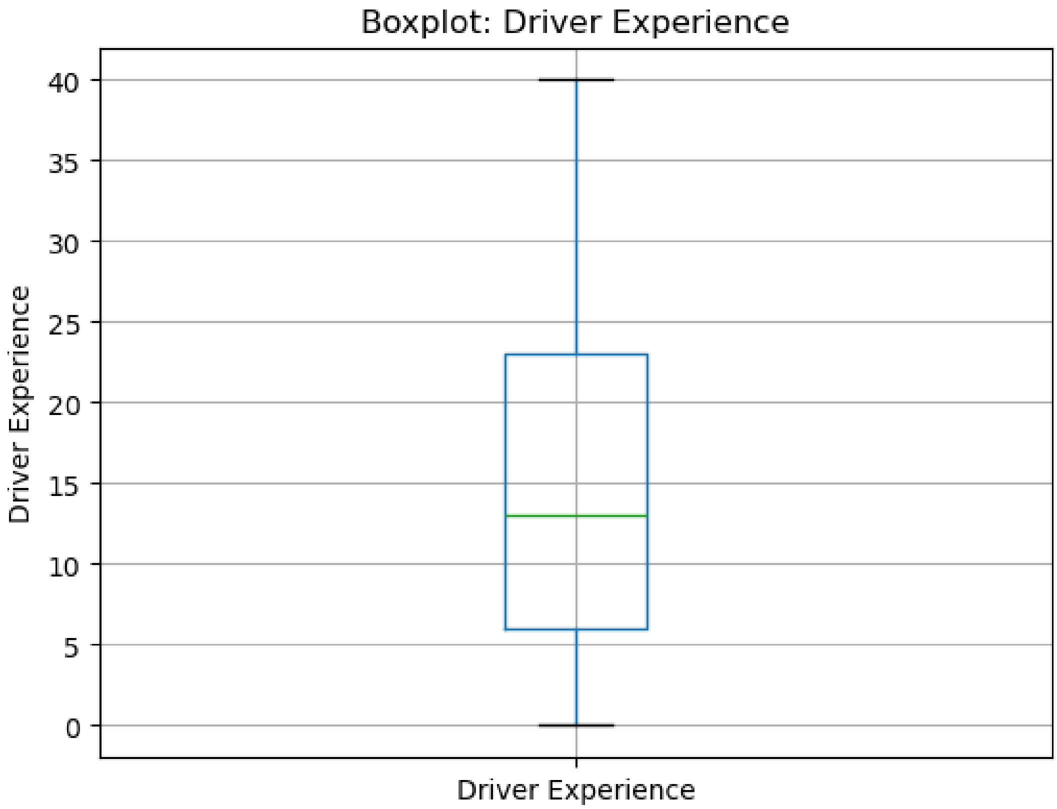

Histogram: Car Manufacturing Year
Count
0
10
20
30
40
50
60
1990
1995
2000
2005
2010
2015
2020
2025
Car Manufacturing Year

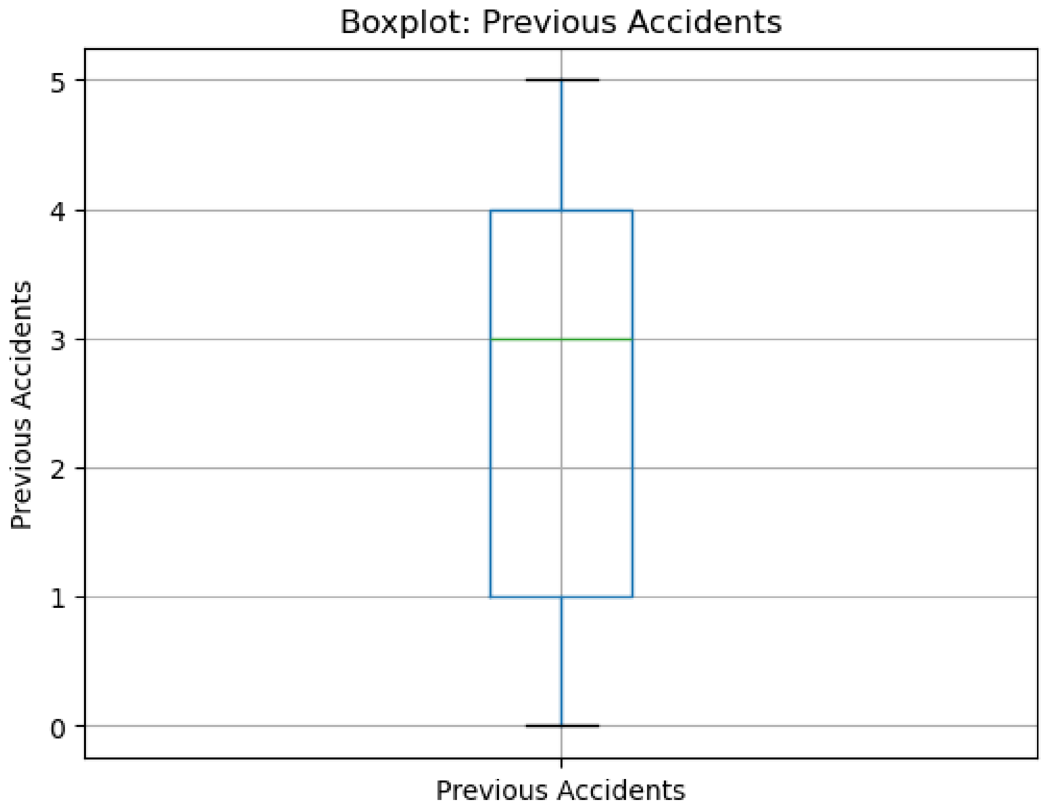

Histogram: Car Age
Count
Car Age
70
60
50
40
30
20
10
0
0
5
10
15
20
25
30
35

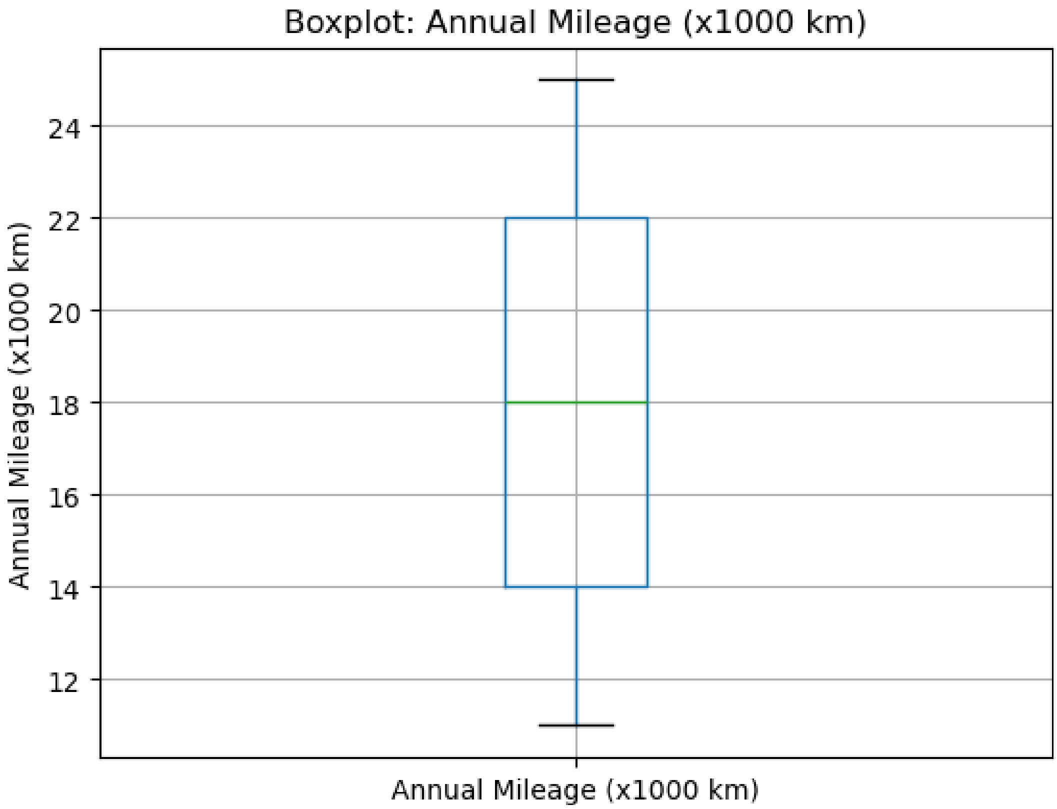


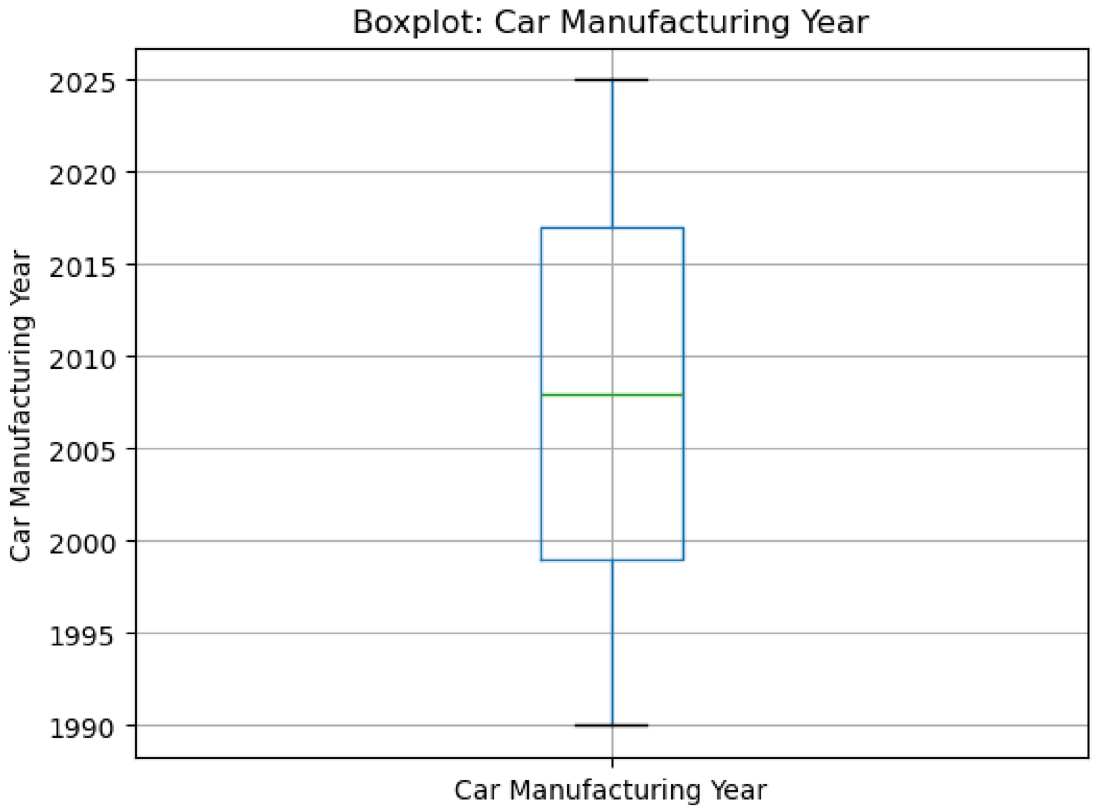
[4]:
```
# 4) Box plots - one chart per column
for col in numeric_cols:
    plt.figure()
    df.boxplot(column=col)
    plt.title(f'Boxplot: {col}')
    plt.ylabel(col)
    plt.show()
```


Boxplot: Driver Age
60
50
40
30
20
Driver Age
Driver Age

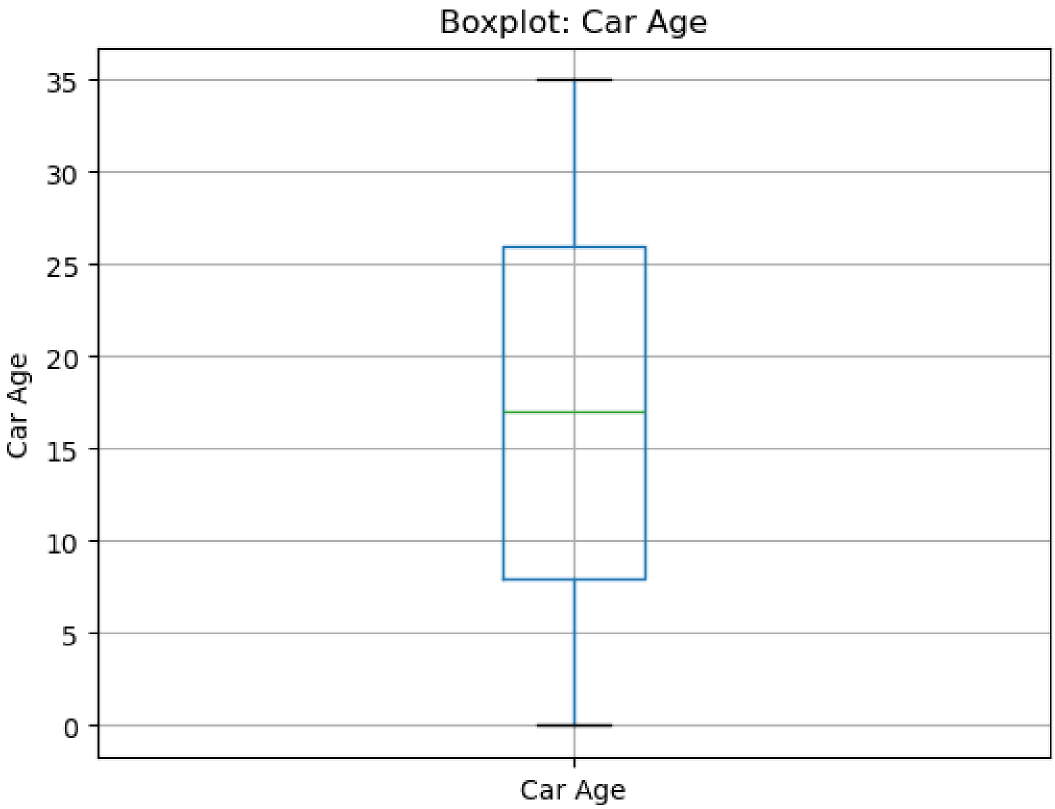

Boxplot: Driver Experience
Driver Experience
40
35
30
25
20
15
10
5
0
Driver Experience

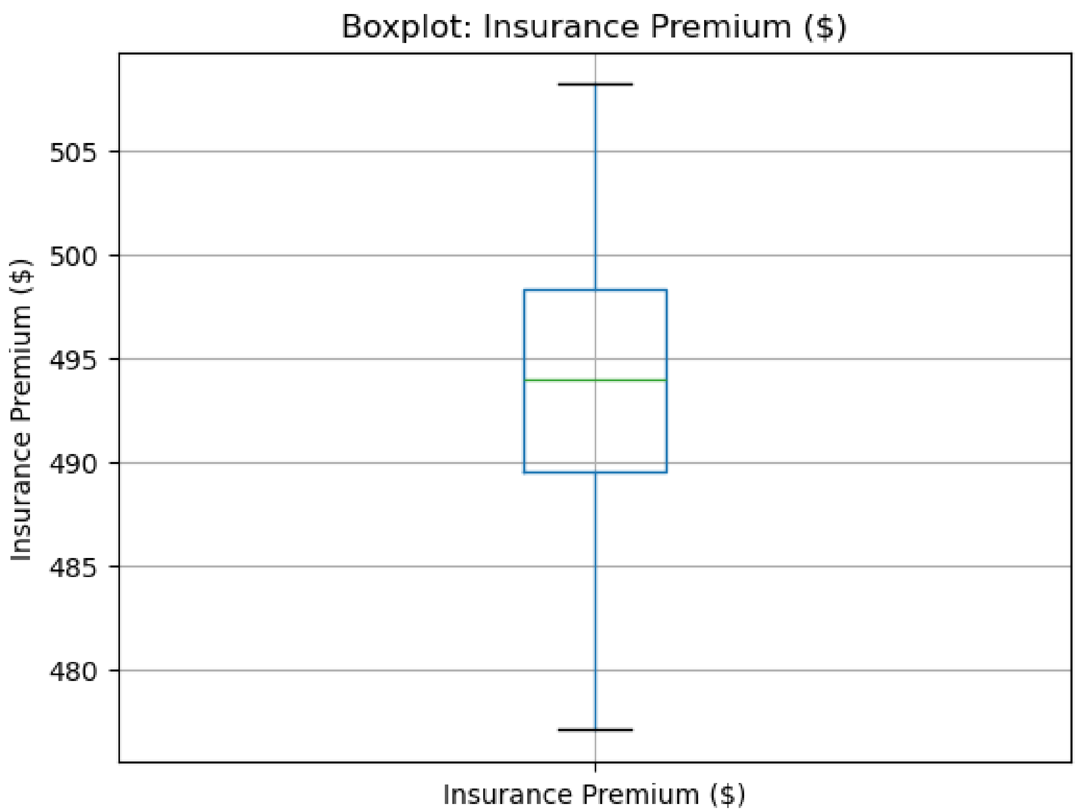

Boxplot: Previous Accidents
5
4
3
2
1
0
Previous Accidents
Previous Accidents


Boxplot: Annual Mileage (x1000 km)
Annual Mileage (x1000 km)
24
22
20
18
16
14
12
Annual Mileage (x1000 km)

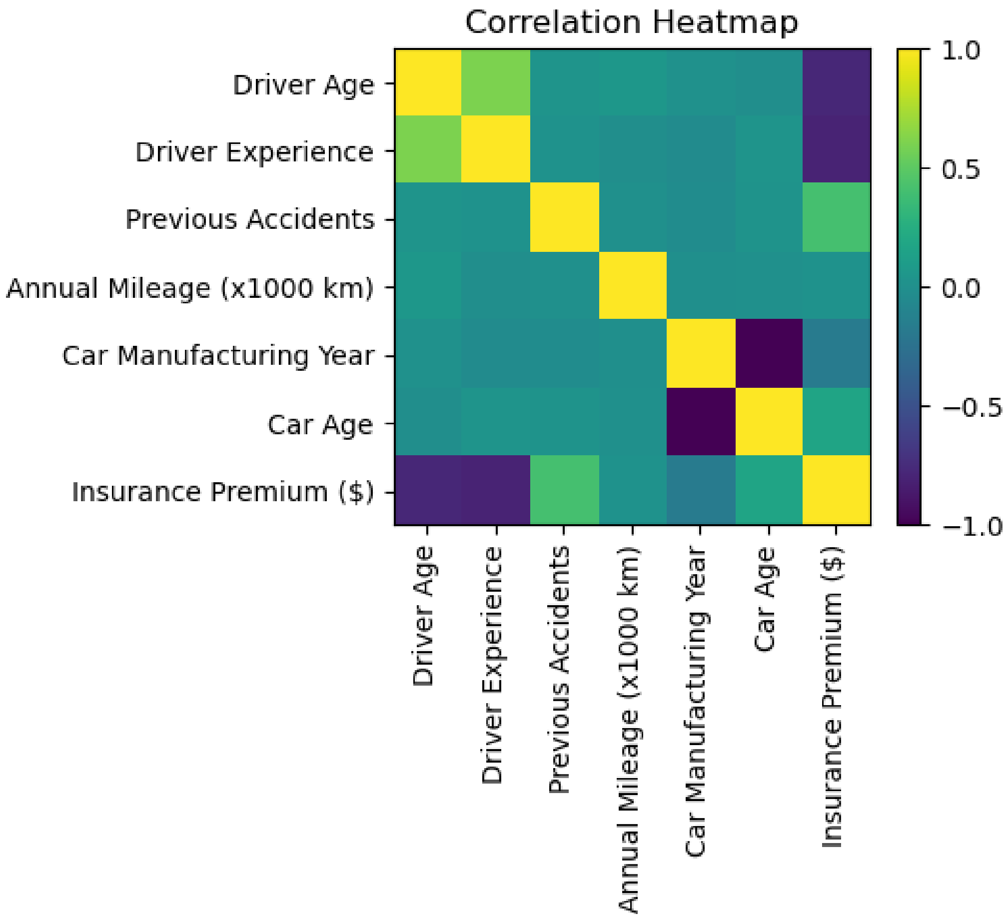


Boxplot: Car Manufacturing Year
Car Manufacturing Year
2025
2020
2015
2010
2005
2000
1995
1990
Car Manufacturing Year


Boxplot: Car Age
Car Age
35
30
25
20
15
10
5
0
Car Age



[5]:
```
# 5) Correlation heatmap
corr = df[numeric_cols].corr(numeric_only=True)
plt.figure(figsize=(6,5))
im = plt.imshow(corr.values, interpolation='nearest')
plt.title('Correlation Heatmap')
plt.xticks(range(len(corr.columns)), corr.columns, rotation=90)
plt.yticks(range(len(corr.index)), corr.index)
plt.colorbar(im, fraction=0.046, pad=0.04)
plt.tight_layout()
plt.show()
display(corr)
```




```
                           Driver Age  Driver Experience  Previous Accidents  \
Driver Age                   1.000000           0.607890            0.031819
Driver Experience            0.607890           1.000000            0.020837
Previous Accidents           0.031819           0.020837            1.000000
Annual Mileage (x1000 km)    0.056822          -0.014424            0.007088
Car Manufacturing Year       0.008187          -0.038194           -0.030123
Car Age                     -0.008187           0.038194            0.030123
Insurance Premium ($)       -0.776848          -0.803323            0.410786

                           Annual Mileage (x1000 km)  Car Manufacturing Year  \
Driver Age                                  0.056822                0.008187
Driver Experience                          -0.014424               -0.038194
Previous Accidents                          0.007088               -0.030123
Annual Mileage (x1000 km)                   1.000000               -0.002898
Car Manufacturing Year                     -0.002898                1.000000
Car Age                                     0.002898               -1.000000
Insurance Premium ($)                       0.022131               -0.171829
```

```
                          Car Age  Insurance Premium ($)
Driver Age               -0.008187              -0.776848
Driver Experience         0.038194              -0.803323
Previous Accidents        0.030123               0.410786
Annual Mileage (x1000 km)  0.002898              0.022131
Car Manufacturing Year   -1.000000              -0.171829
Car Age                   1.000000               0.171829
Insurance Premium ($)     0.171829               1.000000
```

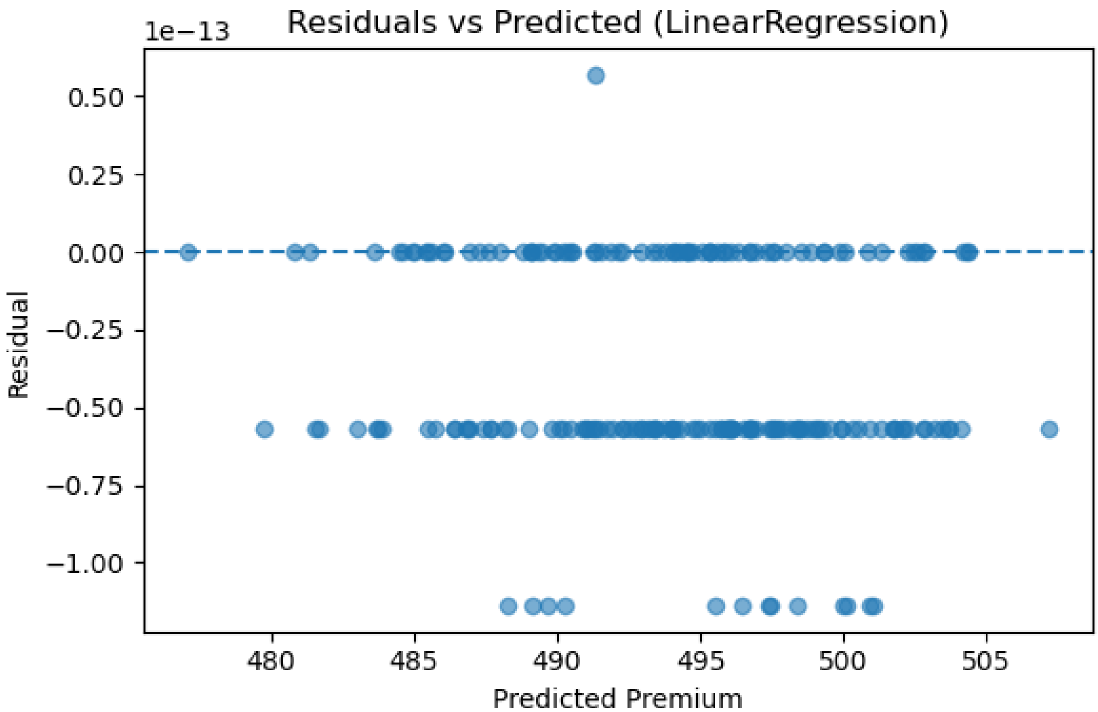
[6]:
```python
# 6) Scatter Plot
plt.figure(figsize=(6,4))
sns.scatterplot(x=df["Driver Experience"],
                y=df["Insurance Premium ($)"],
                alpha=0.5, color="orange")

sns.regplot(x=df["Driver Experience"],
            y=df["Insurance Premium ($)"],
            scatter=False, color="red")

plt.title("Premium vs Driver Experience")
plt.xlabel("Experience (years)")
plt.ylabel("Premium ($)")
plt.show()
```

[12]:
```
# 7) Build and test models
TARGET = "Insurance Premium ($)"
assert TARGET in df.columns, f"Target column '{TARGET}' not found."
X = df.drop(columns=[TARGET])
y = df[TARGET]

num_cols = X.select_dtypes(include=["number"]).columns.tolist()
cat_cols = X.select_dtypes(exclude=["number"]).columns.tolist()

numeric_transformer = Pipeline(steps=[
    ("imputer", SimpleImputer(strategy="median")),
    ("scaler", StandardScaler(with_mean=False))
])

categorical_transformer = Pipeline(steps=[
    ("imputer", SimpleImputer(strategy="most_frequent")),
    ("onehot", OneHotEncoder(handle_unknown="ignore"))
])

preprocessor = ColumnTransformer(transformers=[
    ("num", numeric_transformer, num_cols),
    ("cat", categorical_transformer, cat_cols)
])

X_train, X_test, y_train, y_test = train_test_split(
    X, y, test_size=0.20, random_state=42
)

models = {
    "LinearRegression": LinearRegression(),
    "RidgeCV": RidgeCV(alphas=np.logspace(-2, 2, 9)),  # 0.01..100
    "RandomForest": RandomForestRegressor(n_estimators=200, random_state=42),
    "GradientBoosting": GradientBoostingRegressor(n_estimators=250,␣
 ↪learning_rate=0.1, max_depth=3, random_state=42),
}

results = []
best_model = None
best_name = None
best_rmse = float("inf")

for name, model in models.items():
    pipe = Pipeline(steps=[("prep", preprocessor), ("model", model)])
    pipe.fit(X_train, y_train)
    y_pred = pipe.predict(X_test)
    rmse = mean_squared_error(y_test, y_pred, squared=False)
    mae = mean_absolute_error(y_test, y_pred)
```

```
    r2 = r2_score(y_test, y_pred)
    results.append({"model": name, "test_rmse": rmse, "test_mae": mae,␣
 ↪"test_r2": r2})
    if rmse < best_rmse:
        best_rmse = rmse
        best_model = pipe
        best_name = name

results_df = pd.DataFrame(results).sort_values("test_rmse").
 ↪reset_index(drop=True)
display(results_df)
```

	model	test_rmse	test_mae	test_r2
0	LinearRegression	5.084230e-14	3.808509e-14	1.000000
1	RidgeCV	5.499015e-05	4.545626e-05	1.000000
2	GradientBoosting	3.598881e-01	2.782540e-01	0.996182
3	RandomForest	7.357459e-01	5.486713e-01	0.984044

[13]:
```
# 8) Residual Plot
y_pred_best = best_model.predict(X_test)
residuals = y_test - y_pred_best

plt.figure(figsize=(6,4))
plt.scatter(y_pred_best, residuals, alpha=0.6)
plt.axhline(0, linestyle="--")
plt.title(f"Residuals vs Predicted ({best_name})")
plt.xlabel("Predicted Premium")
plt.ylabel("Residual")
plt.tight_layout()
plt.show()
```



[15]:
```
# 9) Save best model and example inference
model_path = f'best_model_{best_name.replace(" ", "_").lower()}.joblib'
joblib.dump(best_model, model_path)
print('Best model:', best_name)

example = pd.DataFrame([{
    col: (X_train[col].median() if pd.api.types.is_numeric_dtype(X_train[col])␣
 ↪else X_train[col].mode().iloc[0])
    for col in X_train.columns
}])
display(example)
print('Prediction for example row:')
print(best_model.predict(example))
```

```
Best model: LinearRegression

   Driver Age  Driver Experience  Previous Accidents  \
0        42.0               13.0                 3.0

   Annual Mileage (x1000 km)  Car Manufacturing Year  Car Age
0                       18.0                  2008.0     17.0

Prediction for example row:
[494.8]
```

```
[ ]:
```