Project 7: Modeling Car Insurance Claims Outcome

Lawal's Project

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Figure 1: car

1 Project Overview

Insurance companies invest a lot of time and money into optimizing their pricing and accurately estimating the likelihood that customers will make a claim. In many countries insurance it is a legal requirement to have car insurance in order to drive a vehicle on public roads, so the market is very large!

Knowing all of this, On the Road car insurance have requested your services in building a model to predict whether a customer will make a claim on their insurance during the policy period. As they have very little expertise and infrastructure for deploying and monitoring machine learning models, they've asked you to identify the single feature that results in the best performing model, as measured by accuracy, so they can start with a simple model in production.

They have supplied you with their customer data as a csv file called `car_insurance.csv`, along with a table detailing the column names and descriptions below.

Table 1: Customer data

Column	Description
`id`	Unique client identifier
`age`	Client's age:
`gender`	Client's gender:
`driving_experience`	Years the client has been driving:
`education`	Client's level of education:
`income`	Client's income level:
`credit_score`	Client's credit score (between zero and one)
`vehicle_ownership`	Client's vehicle ownership status:
`vehcile_year`	Year of vehicle registration:
`married`	Client's marital status:
`children`	Client's number of children
`postal_code`	Client's postal code
`annual_mileage`	Number of miles driven by the client each year
`vehicle_type`	Type of car:
`speeding_violations`	Total number of speeding violations received by the client
`duis`	Number of times the client has been caught driving under the influence of alcohol
`past_accidents`	Total number of previous accidents the client has been involved in
`outcome`	Whether the client made a claim on their car insurance (response variable):

2 Task

- Identify the single feature of the data that is the best predictor of whether a customer will put in a claim (the `"outcome"` column), excluding the `"id"` column.
- Store as a DataFrame called `best_feature_df`, containing columns named `"best_feature"` and `"best_accuracy"` with the name of the feature with the highest accuracy, and the respective accuracy score.

3 Data Source

Data: The primary data used for this analysis is the car_insurance.csv. See Table 1 for the column names and descriptions.

4 Tools

Jupyter lab

5 Methodology: Steps/Explanations

The necessary libraries was imported, which were `Pandas` and `logit` from `statsmodels.formula.api`

Reading in and exploring the dataset, including imputation of missing values

- The Original dataset was loaded, named `car`.
- The first function, `explore`, was designed to help analyze and clean a dataset by providing a detailed overview of its structure and content, and it also optionally imputes missing values. Here's a step-by-step explanation:

1. **Function creation and its arguments**: `data`, the DataFrame to analyze; `head_rows`, the number of rows to display from the start of the DataFrame (default: 5); `group_by_col`, the column used to group data for imputing missing values (default: None); `cols_to_impute`, the list of columns where missing values will be filled with the group mean (default: None).

```
def explore(data, head_rows=5, group_by_col=None, cols_to_impute=None):
```

2. **Function Task 1**: Prints information about the DataFrame, such as:

- Number of rows and columns.
- Data types of each column.
- Non-null counts for each column.

```
print("\n--- DataFrame Info ---\n")
data.info()
```

3. **Function Task 2**: Displays summary statistics for all columns, including:

- For numerical data: Mean, standard deviation, min, max, and percentiles.
- For categorical data: Frequency counts (mode) and unique counts.

```
print("\n--- Summary Statistics ---\n")
print(data.describe(include='all'))
```

3. **Function Task 3**: Displays the first head_rows rows (default: 5) of the DataFrame to give a preview of the data.

```
print(f"\n--- First {head_rows} Rows ---\n")
print(data.head(head_rows))
```

4. **Function Task 4**: Iterates over each column and prints the unique values present in it. Helps understand the distinct data points for each column.

```
print("\n--- Unique Values ---\n")
for col in data.columns:
    print(f"{col}: {data[col].unique()}")
```

5. **Function Task 5**: Fills missing values (`NaN`) in the specified columns (`cols_to_impute`) by grouping data based on `group_by_col` and calculating the mean for each group.

- Steps:
  - Groups the data by the column specified in `group_by_col`.
  - Calculates the mean for the columns listed in `cols_to_impute` for each group.
  - Fills missing values in each column by mapping the group means to the corresponding rows.
- Error Handling:
  - Ensures the function doesn't crash if the specified column is not found or if an error occurs during imputation.

```
if group_by_col and cols_to_impute:
    print("\n--- Imputing Missing Values ---\n")
    try:
        group_means = data.groupby(group_by_col)[cols_to_impute].mean().to_dict()
        for col in cols_to_impute:
            if col in data.columns:
                print(f"Imputing missing values in '{col}' based on group means of '{group_by_col
                data[col] = data[col].fillna(data[group_by_col].map(group_means[col]))
            else:
                print(f"Column '{col}' not found in the dataset.")
    except Exception as e:
        print(f"Error while imputing missing values: {e}")
```

6. **Function Task 6**: After the imputation, checks and prints the count of missing values in each column to verify if gaps were successfully filled.

```
print("\n--- Any missing values again ? ---\n")
print(data.isna().sum())
```

Finding the best performing model, with the highest accuracy.

- The second function, `best_logmodel`, was designed to identify the single best feature in a dataset for predicting a binary outcome using logistic regression with the statsmodels library. Here's a detailed explanation:

1. **Function creation and its arguments**: `data`, the input dataset for modeling as a pandas DataFrame; `outcome_column`, the target column (dependent variable) representing the outcome being predicted (default: 'outcome'); `id_column`, a unique identifier column to exclude from the analysis (default: 'id').

```
def best_logmodel(data, outcome_column='outcome', id_column='id'):
```

2. **Function Task**: Creates a new DataFrame (`data1`) by removing the `id_column` (not predictive) and the `outcome_column` (target variable) from the list of features. The remaining columns are treated as potential predictors.

```
data1 = data.drop(columns=[id_column, outcome_column])
```

3. **Initialize Tracking Variables**: `best_feature`, placeholder for the name of the feature with the highest accuracy and `best_accuracy`, tracks the best accuracy score encountered during the iteration.

```
best_feature = None
best_accuracy = 0
```

4. **Loop Through Each Feature**: Iterates through all the columns (features) in data1 to evaluate their predictive power for the `outcome_column`.

```
for col in data1.columns:
```

5. **Create the Logistic Regression Formula**: Constructs a formula for logistic regression in the form `"outcome_column ~ feature_column"`.

```
formula = f"{outcome_column} ~ {col}"
```

6. **Fit Logistic Regression Model**: Fits a logistic regression model for the current feature using the `logit` function from `statsmodels`. The 'disp=False argument suppresses output during model fitting.

```
model = logit(formula=formula, data=data).fit(disp=False)
```

7. **Generate Confusion Matrix**: Produces a confusion matrix for the logistic regression model's predictions.

```
confusion_matrix = model.pred_table()
```

- **Confusion Matrix Layout**:

```
[[TN, FP],    # TN = True Negatives, FP = False Positives
 [FN, TP]]    # FN = False Negatives, TP = True Positives
```

8. **Calculates the model's accuracy from the confusion matrix**:

- `TP`: True Positives (correctly predicted positives).
- `TN`: True Negatives (correctly predicted negatives).
- `T`: Total number of predictions.
- **Accuracy Formula**:

$$\text{Accuracy} = \frac{\text{TP} + \text{TN}}{\text{Total Predictions}}$$

9. **Update the Best Feature**: Compares the current feature's accuracy with the best accuracy seen so far. If the current feature has a higher accuracy, update `best_feature` and `best_accuracy`.

```
if accuracy > best_accuracy:
    best_feature = col
    best_accuracy = accuracy
```

10. **Store Results in a DataFrame**: Summarizes the results into a pandas DataFrame with:

- `best_feature`: The name of the feature with the highest accuracy.
- `best_accuracy`: The corresponding accuracy score.

```
best_feature_df = pd.DataFrame({
    "best_feature": [best_feature],
    "best_accuracy": [best_accuracy]
})
```

11. **Return the Results**: Returns the DataFrame so that the results can be used or displayed.

```
return best_feature_df
```

6 Data Analysis

```python
# Import required modules
import pandas as pd
from statsmodels.formula.api import logit

# Start coding!
car = pd.read_csv("car_insurance.csv")

# Exploring the data
```

```python
def explore(data, head_rows=5, group_by_col=None, cols_to_impute=None):
    """
    Explores the given DataFrame by displaying basic information, summary statistics,
    the first few rows, unique values, and imputes missing values with group means if specified.

    Parameters:
        data (pd.DataFrame): The DataFrame to explore.
        head_rows (int): Number of rows to display for the head of the DataFrame. Default is 5.
        group_by_col (str): Column name to group by for imputing missing values. Default is None.
        cols_to_impute (list): List of column names to impute missing values. Default is None.
    """
    print("\n--- DataFrame Info ---\n")
    data.info()

    print("\n--- Summary Statistics ---\n")
    print(data.describe(include='all'))  # Include all data types in describe()

    print(f"\n--- First {head_rows} Rows ---\n")
    print(data.head(head_rows))

    print("\n--- Unique Values ---\n")
    for col in data.columns:
        print(f"{col}: {data[col].unique()}")

    # Impute missing values if group_by_col and cols_to_impute are specified
    if group_by_col and cols_to_impute:
        print("\n--- Imputing Missing Values ---\n")
        try:
            group_means = data.groupby(group_by_col)[cols_to_impute].mean().to_dict()  # Group me
            for col in cols_to_impute:
                if col in data.columns:
                    print(f"Imputing missing values in '{col}' based on group means of '{group_by
                    data[col] = data[col].fillna(data[group_by_col].map(group_means[col]))
                else:
                    print(f"Column '{col}' not found in the dataset.")
        except Exception as e:
            print(f"Error while imputing missing values: {e}")

    print("\n--- Any missing values again ? ---\n")
    print(data.isna().sum())

# Example usage
# explore(your_data, group_by_col="outcome", cols_to_impute=["credit_score", "annual_mileage"])
```

```
explore(car, group_by_col="outcome", cols_to_impute=["credit_score", "annual_mileage"])

def best_logmodel(data, outcome_column='outcome', id_column='id'):
    """
    Identifies the single best feature for predicting the outcome column using logistic regressio
    with statsmodels. Calculates accuracy directly from the confusion matrix.

    Parameters:
        data (pd.DataFrame): The dataset containing features and the outcome column.
        outcome_column (str): The name of the target column.
        id_column (str): The name of the column to exclude from analysis.

    Returns:
        pd.DataFrame: A DataFrame with the best feature and its accuracy score.
    """
    # Exclude ID and outcome columns from columns set
    data1 = data.drop(columns=[id_column, outcome_column])

    best_feature = None
    best_accuracy = 0

    # Iterate through each columns
    for col in data1.columns:
        # Create formula for logistic regression
        formula = f"{outcome_column} ~ {col}"

        # Fit logistic regression model on the entire dataset
        model = logit(formula=formula, data=data).fit(disp=False)

        # Generate confusion matrix using pred_table()
        confusion_matrix = model.pred_table()

        # Calculate accuracy from confusion matrix
        TP = confusion_matrix[1, 1]
        TN = confusion_matrix[0, 0]
        T = confusion_matrix.sum()
        accuracy = (TP + TN) / T

        # Update the best feature if this one is better
        if accuracy > best_accuracy:
            best_feature = col
            best_accuracy = accuracy

    # Store results in a DataFrame
```

```python
    best_feature_df = pd.DataFrame({
        "best_feature": [best_feature],
        "best_accuracy": [best_accuracy]
    })

    return best_feature_df

# Example usage
# best_feature_df = best_logmodel(your_data)
# print(best_feature_df)

best_feature_df = best_logmodel(car)

print(best_feature_df)
```

```
--- DataFrame Info ---

<class 'pandas.core.frame.DataFrame'>
RangeIndex: 10000 entries, 0 to 9999
Data columns (total 18 columns):
 #   Column               Non-Null Count  Dtype
---  ------               --------------  -----
 0   id                   10000 non-null  int64
 1   age                  10000 non-null  int64
 2   gender               10000 non-null  int64
 3   driving_experience   10000 non-null  object
 4   education            10000 non-null  object
 5   income               10000 non-null  object
 6   credit_score         9018 non-null   float64
 7   vehicle_ownership    10000 non-null  float64
 8   vehicle_year         10000 non-null  object
 9   married              10000 non-null  float64
 10  children             10000 non-null  float64
 11  postal_code          10000 non-null  int64
 12  annual_mileage       9043 non-null   float64
 13  vehicle_type         10000 non-null  object
 14  speeding_violations  10000 non-null  int64
 15  duis                 10000 non-null  int64
 16  past_accidents       10000 non-null  int64
 17  outcome              10000 non-null  float64
dtypes: float64(6), int64(7), object(5)
memory usage: 1.4+ MB

--- Summary Statistics ---
```

```
                 id          age       gender driving_experience  \
count  10000.000000  10000.000000  10000.000000              10000
unique          NaN          NaN          NaN                  4
top             NaN          NaN          NaN               0-9y
freq            NaN          NaN          NaN               3530
mean  500521.906800     1.489500     0.499000                NaN
std   290030.768758     1.025278     0.500024                NaN
min      101.000000     0.000000     0.000000                NaN
25%   249638.500000     1.000000     0.000000                NaN
50%   501777.000000     1.000000     0.000000                NaN
75%   753974.500000     2.000000     1.000000                NaN
max   999976.000000     3.000000     1.000000                NaN

          education       income  credit_score  vehicle_ownership  \
count         10000        10000   9018.000000       10000.000000
unique            3            4           NaN                NaN
top     high school  upper class           NaN                NaN
freq           4157         4336           NaN                NaN
mean            NaN          NaN      0.515813           0.697000
std             NaN          NaN      0.137688           0.459578
min             NaN          NaN      0.053358           0.000000
25%             NaN          NaN      0.417191           0.000000
50%             NaN          NaN      0.525033           1.000000
75%             NaN          NaN      0.618312           1.000000
max             NaN          NaN      0.960819           1.000000

       vehicle_year       married      children   postal_code  annual_mileage  \
count         10000  10000.000000  10000.000000  10000.000000     9043.000000
unique            2           NaN           NaN           NaN             NaN
top     before 2015           NaN           NaN           NaN             NaN
freq           6967           NaN           NaN           NaN             NaN
mean            NaN      0.498200      0.688800  19864.548400    11697.003207
std             NaN      0.500022      0.463008  18915.613855     2818.434528
min             NaN      0.000000      0.000000  10238.000000     2000.000000
25%             NaN      0.000000      0.000000  10238.000000    10000.000000
50%             NaN      0.000000      1.000000  10238.000000    12000.000000
75%             NaN      1.000000      1.000000  32765.000000    14000.000000
max             NaN      1.000000      1.000000  92101.000000    22000.000000

       vehicle_type  speeding_violations         duis  past_accidents  \
count         10000         10000.000000  10000.00000    10000.000000
unique            2                  NaN          NaN             NaN
top           sedan                  NaN          NaN             NaN
freq           9523                  NaN          NaN             NaN
```

```
mean           NaN              1.482900     0.23920        1.056300
std            NaN              2.241966     0.55499        1.652454
min            NaN              0.000000     0.00000        0.000000
25%            NaN              0.000000     0.00000        0.000000
50%            NaN              0.000000     0.00000        0.000000
75%            NaN              2.000000     0.00000        2.000000
max            NaN             22.000000     6.00000       15.000000

             outcome
count   10000.000000
unique           NaN
top              NaN
freq             NaN
mean        0.313300
std         0.463858
min         0.000000
25%         0.000000
50%         0.000000
75%         1.000000
max         1.000000

--- First 5 Rows ---

       id  age  gender driving_experience    education         income  \
0  569520    3       0               0-9y  high school    upper class
1  750365    0       1               0-9y         none        poverty
2  199901    0       0               0-9y  high school  working class
3  478866    0       1               0-9y   university  working class
4  731664    1       1             10-19y         none  working class

   credit_score  vehicle_ownership vehicle_year  married  children  \
0      0.629027                1.0   after 2015      0.0       1.0
1      0.357757                0.0  before 2015      0.0       0.0
2      0.493146                1.0  before 2015      0.0       0.0
3      0.206013                1.0  before 2015      0.0       1.0
4      0.388366                1.0  before 2015      0.0       0.0

   postal_code  annual_mileage vehicle_type  speeding_violations  duis  \
0        10238         12000.0        sedan                    0     0
1        10238         16000.0        sedan                    0     0
2        10238         11000.0        sedan                    0     0
3        32765         11000.0        sedan                    0     0
4        32765         12000.0        sedan                    2     0

   past_accidents  outcome
```

```
0               0      0.0
1               0      1.0
2               0      0.0
3               0      0.0
4               1      1.0

--- Unique Values ---

id: [569520 750365 199901 ... 468409 903459 442696]
age: [3 0 1 2]
gender: [0 1]
driving_experience: ['0-9y' '10-19y' '20-29y' '30y+']
education: ['high school' 'none' 'university']
income: ['upper class' 'poverty' 'working class' 'middle class']
credit_score: [0.62902731 0.35775712 0.49314579 ... 0.47094023 0.36418478 0.43522478]
vehicle_ownership: [1. 0.]
vehicle_year: ['after 2015' 'before 2015']
married: [0. 1.]
children: [1. 0.]
postal_code: [10238 32765 92101 21217]
annual_mileage: [12000. 16000. 11000. 13000. 14000. 10000.  8000.    nan 18000. 17000.
  7000. 15000.  9000.  5000.  6000. 19000.  4000.  3000.  2000. 20000.
 21000. 22000.]
vehicle_type: ['sedan' 'sports car']
speeding_violations: [ 0  2  3  7  6  4 10 13  1  5  9  8 12 11 15 17 19 18 16 14 22]
duis: [0 2 1 3 4 5 6]
past_accidents: [ 0  1  3  7  2  5  4  6  8 10 11  9 12 14 15]
outcome: [0. 1.]

--- Imputing Missing Values ---

Imputing missing values in 'credit_score' based on group means of 'outcome'
Imputing missing values in 'annual_mileage' based on group means of 'outcome'

--- Any missing values again ? ---

id                     0
age                    0
gender                 0
driving_experience     0
education              0
income                 0
credit_score           0
vehicle_ownership      0
vehicle_year           0
```

```
married               0
children              0
postal_code           0
annual_mileage        0
vehicle_type          0
speeding_violations   0
duis                  0
past_accidents        0
outcome               0
dtype: int64
         best_feature  best_accuracy
0  driving_experience         0.7771
```

7 Result/Findings

- The analysis identified `driving_experience` (indicating the years the client has been driving) as the best predictor of whether a customer will file a claim, with an accuracy score of 77.7%. This indicates that the model correctly predicted claims and non-claims in approximately 78 out of 100 cases, making this feature a significant factor in claim prediction.

8 Recommendations

None

9 Limitations

None

10 Conclusion

My analysis identified `driving_experience` (years of driving) as the strongest predictor of claim submissions, achieving an accuracy score of 77.7%. This result highlights the importance of driving experience in assessing customer risk. The model correctly classified claims and non-claims in 78 out of 100 cases.

Logistic regression was used to evaluate the predictive power of individual features, and accuracy was calculated using a confusion matrix. The prominence of driving experience suggests that more experienced drivers may exhibit different risk profiles, which could guide targeted policy offerings.

I recommend incorporating this insight into your risk assessment models.

11 References

1. For loop in Intermediate Python Course for Associate Data Scientist in Python Carrer Track in DataCamp Inc by Hugo Bowne-Henderson.
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5. Python For Data Analysis 3E (Online) by Wes Mckinney Click here to preview.