CS 484: Introduction to Machine Learning

Fall Semester 2023 Assignment 3

Name: Sai Ram Oduri

ID : A20522183

We provide you with the **claim_history.xlsx** which contains 10,302 observations on various vehicles. You will use the observations in this Excel file to train models that predict the usage of a vehicle. Your models will use the following variables.

Label Field

- **CAR_USE**. Vehicle Usage. It has two categories, namely, *Commercial* and *Private*.

Nominal Predictor

- **CAR_TYPE**. Vehicle Type. It has six categories, namely, *Minivan*, *Panel Truck*, *Pickup*, *SUV*, *Sports Car*, and *Van*.
- **OCCUPATION**. Occupation of Vehicle Owner. It has nine categories, namely, *Clerical*, *Home Maker*, *Medical*, *Lawyer*, *Management*, *Skilled Worker*, *STEM*, *Student*, and *Not Reported*.

Ordinal Predictor

- **EDUCATION**. Highest Education Level of Vehicle Owner. It has five ordered categories which are *Below High School* < *High School* < *Bachelors* < *Masters* < *Doctors*.

Although a decision tree can accommodate missing values in the predictors, we will use only observations where there are no missing values in all the above four variables. After dropping the missing values, we will use all the 100% complete observations for training both models.

For each observation, you will calculate the predicted probabilities for CAR_USE = *Commercial* and CAR_USE = *Private*. You will classify the observation in the CAR_USE category that has the highest predicted probability. In case of ties, choose the *Private* category.

Question 1 (50 points)

You will train a classification tree model with the following specifications:

- The maximum depth is two.
- The split criterion is the Entropy metric.
- An observation in the parent node will be assigned to the left child node if the splitting criterion is evaluated to be True. Otherwise, it will be assigned to the right child node.

Since the sklearn tree module does not handle string features, you must write Python codes to find the optimal split for a string feature. You must use values of a nominal string AS IS. Do not encode the nominal features into dummy columns. To find all the possible splits of a nominal predictor, we suggest the itertools.combinations() function to you.

a) (20 points) Please describe the leaf nodes of the classification tree. Your description should include these five pieces of information: (1) Splitting Criterion, (2) Number of Observations, (3) Predicted Probabilities of CAR_USE, (4) Predicted CAR_USE category, and (5) Split Entropy Value.

Ans.

```
Total Count:  10302
Root Node Entropy:  0.9489621493401781

Prediction probabilities of left observations are :

['EDUCATION', 0.6670194998377932, [[0], [1, 2, 3, 4]], [[823, CAR_USE
Commercial    216
Private       607
Name: LEFT, dtype: int64, 0.8304276080710689], [3029, CAR_USE
Commercial    2559
Private        470
Name: RIGHT, dtype: int64, 0.6226204001098349]], 'Entropy', 3029]

Prediction probabilities of right observations are :

['CAR_TYPE', 0.3274450052616845, [['Minivan', 'SUV', 'Sports Car'], ['Pickup', 'Panel Truck', 'Van']], [[4594, CAR_USE
Commercial      30
Private       4564
Name: LEFT, dtype: int64, 0.056791153992247115], [1856, CAR_USE
Commercial    984
Private       872
Name: RIGHT, dtype: int64, 0.9973716177249364]], 'Entropy', 1856]
```

The root note entropy is given by 0.94896 or 94.89 %

Then LB contains Education, 0.667019 with entropy 3029

The RB contains the CAR TYPE with entropy 1856

```
Total Number of Observations and Probabilities :

CAR_USE  Commercial  Private
Leaf
0              216      607
1             2559      470
2               30     4564
3              984      872
CAR_USE   Commercial      Private
Leaf
0       0.2624544350 0.7375455650
1       0.8448332783 0.1551667217
2       0.0065302569 0.9934697431
3       0.5301724138 0.4698275862
```

b) (10 points) Let us study a fictitious person. The person works in a *STEM* occupation, has an education level of *Masters*, and owns a *Minivan*. What are the Car Usage probabilities?

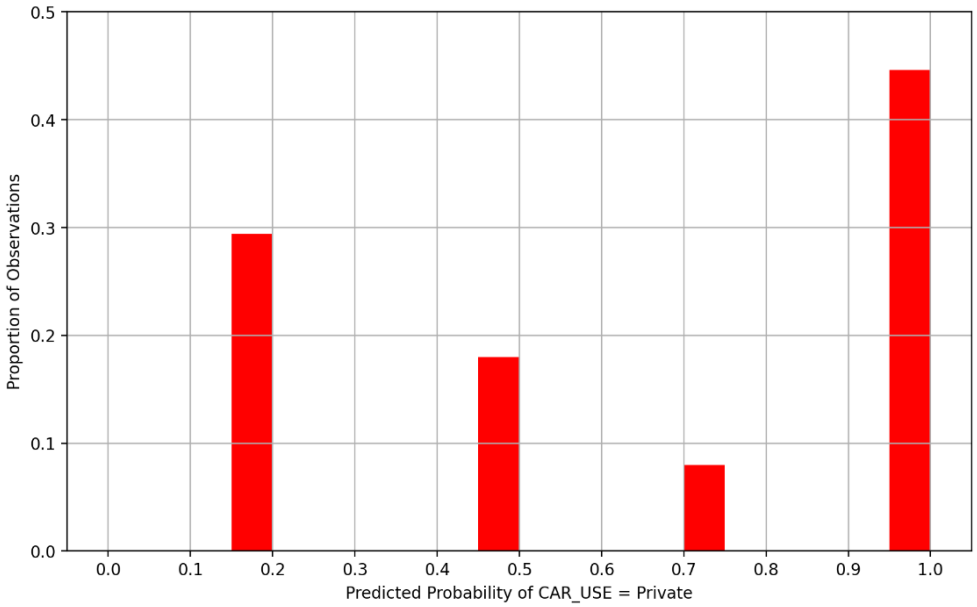
```
CAR Uses Probability

Commercial, Private
0.006530256856769699   0.9934697431432303
Predicted CAR_USE: Private
```

The probabilities of commercial car use is 0.65%
Probabilities of private car use is 99.34%

c) (10 points) Let us study another fictitious person. The person is a *Student*, has a *High School* level of education, and owns a *Pickup*. What are the Car Usage probabilities?

```
CAR Uses Probability

Commercial, Private
0.8448332783096731   0.15516672169032683
Predicted CAR_USE: Commercial
```

d) (5 points) Generate a histogram of the predicted probabilities of CAR_USE = *Private*. The bin width is 0.05. The vertical axis is the proportion of observations.



e) (5 points) Finally, what is the misclassification rate of the Classification Tree model?

```
The Misclassification rate of the Classification Tree model :
15.414482624733061
```

Question 2 (50 points)

You will train a Naïve Bayes model with a Laplace/Lidstone value of 0.01.

a) (10 points) What are the Class Probabilities?

```
Commercial  Private
[0.36779266 0.63220734]
```

b) (10 points) Cross-tabulate the label variable by each predictor and show the resulting table. The table must contain the frequency counts and the row probabilities in each label class.

For Car type

```
CAR_TYPE    Minivan  Panel Truck  Pickup   SUV  Sports Car  Van
CAR_USE
Commercial      553          853    1068   555         200  560
Private        2141            0     704  2328         979  361

 CAR_TYPE     Minivan  Panel Truck    Pickup       SUV  Sports Car       Van
CAR_USE
Commercial  0.145949     0.225125  0.281869  0.146477    0.052784  0.147796
Private     0.328727     0.000000  0.108092  0.357439    0.150315  0.055428
```

For Occupation row type

```
OCCUPATION  Clerical  Home Maker  Lawyer  Management  Medical  Not Reported  \
CAR_USE
Commercial       285          57       0         308        0           593
Private         1305         786    1031         949      321            72

OCCUPATION  STEM  Skilled Worker  Student
CAR_USE
Commercial   364            1735      447
Private     1044             553      452

 OCCUPATION  Clerical  Home Maker    Lawyer  Management   Medical  \
CAR_USE
Commercial  0.075218    0.015044  0.000000    0.081288  0.000000
Private     0.200368    0.120682  0.158299    0.145709  0.049286

OCCUPATION  Not Reported      STEM  Skilled Worker   Student
CAR_USE
Commercial      0.156506  0.096068        0.457904  0.117973
Private         0.011055  0.160295        0.084907  0.069400
```

For education type

```
EDUCATION   Bachelors  Below High School  Doctors  High School  Masters
CAR_USE
Commercial       1191                326      302         1438      532
Private          1632               1189      632         1514     1546

 EDUCATION   Bachelors  Below High School   Doctors  High School   Masters
CAR_USE
Commercial   0.314331           0.086039  0.079704     0.379520  0.140406
Private      0.250576           0.182558  0.097037     0.232458  0.237371
```

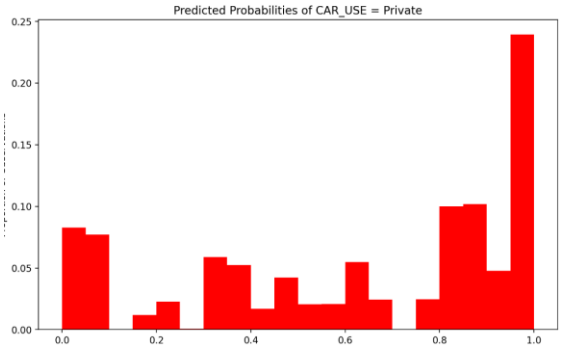
c) (10 points) Let us study a fictitious person. The person works in a *Skilled Worker* occupation, has an education level of *Doctors*, and owns an *SUV*. What are the Car Usage probabilities?

```
The Car Usage probabilities are :

 Commercial  Private
 [[0.5136312 0.4863688]]
```

d) (10 points) Let us study another fictitious person. The person works in a *Management* occupation, has a *Below High School* level of education, and owns a *Sports Car*. What are the Car Usage probabilities?

```
The Car Usage probabilities are :

 Commercial  Private
 [[0.0509781 0.9490219]]
```

e) (5 points) Generate a histogram of the predicted probabilities of CAR_USE = *Private*. The bin width is 0.05. The vertical axis is the proportion of observations.



f) (5 points) Finally, what is the misclassification rate of the Naïve Bayes model?

Ans.

```
The misclassification rate is :  0.1280333915744516
```

The misclassification ratio is 12.8034%