FINAL PROJECT | CODE
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Libraries

In [1]:
```
# utilities
import janitor
import math
import numpy as np
import pandas as pd

# data
from tensorflow.keras.datasets import cifar10

# preprocessing
from sklearn.model_selection import train_test_split
from sklearn.preprocessing import StandardScaler
from tensorflow.keras.utils import to_categorical

# classifiers
from sklearn.ensemble import GradientBoostingClassifier
from sklearn.ensemble import RandomForestClassifier
from sklearn.svm import SVC
from sklearn.model_selection import GridSearchCV
import tensorflow as tf
from tensorflow import keras
from tensorflow.keras import Sequential
from tensorflow.keras.layers import Dense
from tensorflow.keras.layers import Conv2D
from tensorflow.keras.layers import Flatten
from tensorflow.keras.layers import MaxPooling2D
from tensorflow.keras.layers import Dropout
from tensorflow.keras.callbacks import EarlyStopping

# metrics
from sklearn.metrics import classification_report
from sklearn.metrics import confusion_matrix

# plotting
import matplotlib as mpl
import matplotlib.pyplot as plt
import seaborn as sns
```

Initializations

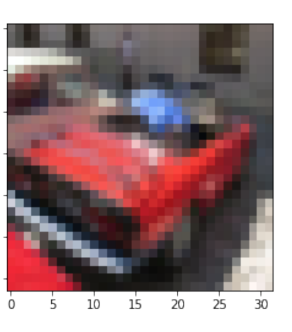
In [2]:
```
# plotting
sns.set_palette('Oranges')
sns.color_palette("YlOrBr")

# printing
np.set_printoptions(precision=2)
pd.set_option('precision', 2)

# runtime
import warnings
warnings.filterwarnings('ignore')
```

In [3]:
```
 # my functions
def _get_cifar(reduce=True):

    # import image data
    (X_train_all, y_train_all), (X_test_all, y_test_all) = cifar10.load_data()

    # reduce data size for document rendering purposes
    if(reduce):
        X_train_all, y_train_all = _reduce_cifar(X_train_all, y_train_all)
        X_test_all, y_test_all = _reduce_cifar(X_test_all, y_test_all)

    # we only need car and truck images
    train_index = np.where((y_train_all == 1) | (y_train_all == 9))[0] # train
    X_train = X_train_all[train_index]
    y_train = y_train_all[train_index]
    test_index = np.where((y_test_all == 1) | (y_test_all == 9))[0] # test
    X_test = X_test_all[test_index]
    y_test = y_test_all[test_index]

    # cnn uses validation datasets
    X_train, X_valid, y_train, y_valid = train_test_split(X_train, y_train, test_size=.5, stratify=y_train, random_sta
te=1)

    # though a multiclass problem, convert labels so we can get recall and precision
    y_train[y_train == 1] = 0
    y_train[y_train == 9] = 1
    y_valid[y_valid == 1] = 0
    y_valid[y_valid == 9] = 1
    y_test[y_test == 1] = 0
    y_test[y_test == 9] = 1

    print('X_train shape: {}'.format(X_train.shape))
    print('y_train shape: {}'.format(y_train.shape))
    print('X_valid shape: {}'.format(X_valid.shape))
    print('y_valid shape: {}'.format(y_valid.shape))
    print('X_test shape: {}'.format(X_test.shape))
    print('y_test shape: {}'.format(y_test.shape))

    return X_train, y_train, X_valid, y_valid, X_test, y_test

def _reduce_cifar(X, y, fraction=0.1):

    # recombine image with its label
    df = pd.DataFrame(list(zip(X, y)), columns =['Image', 'label'])

    # get a sample of the data
    val = df.sample(frac=fraction)

    # seperate them back out
    X_ = np.array([ i for i in list(val['Image'])])
    y_ = np.array([ [i[0]] for i in list(val['label'])])
    return (X_, y_)

def _classification_metrics(y, y_hat):
    print ('Confusion Matrix')
    print(confusion_matrix(y, y_hat, labels=[1,0]))
    print('')
    print ('Classification Report')
    print(classification_report(y, y_hat))

def _prob_to_pred(p):
    return list(map(lambda p: int(p[0] <= p[1]), p))
```

EDA

In [4]:
```
# get image data, don't need validation at this point
X_train, y_train, _, _, X_test, y_test = _get_cifar()

# show an example image
supress = plt.imshow(X_train[1])
```

```
X_train shape: (493, 32, 32, 3)
y_train shape: (493, 1)
X_valid shape: (493, 32, 32, 3)
y_valid shape: (493, 1)
X_test shape: (203, 32, 32, 3)
y_test shape: (203, 1)
```



In [5]:
```
X_train = X_train.reshape(X_train.shape[0], -1)
y_train = y_train.reshape(y_train.shape[0],)
X_test = X_test.reshape(X_test.shape[0], -1)
y_test = y_test.reshape(y_test.shape[0],)

# standardize the training and test data
scaler = StandardScaler()
X_train = scaler.fit_transform(X_train)
X_test = scaler.transform(X_test)
```

Non-Neural Net Classifiers

In [6]:
```
# support vector machines
model_svc = SVC(kernel = 'rbf')
model_svc.fit(X_train, y_train)
preds_svc = model_svc.predict(X_test)
_classification_metrics(y_test, preds_svc)
```

```
Confusion Matrix
[[65 28]
 [34 76]]

Classification Report
              precision    recall  f1-score   support

           0       0.73      0.69      0.71       110
           1       0.66      0.70      0.68        93

    accuracy                           0.69       203
   macro avg       0.69      0.69      0.69       203
weighted avg       0.70      0.69      0.70       203
```

In [7]:
```
# random forest
model_forest = RandomForestClassifier()
model_forest.fit(X_train, y_train)
preds_forest = model_forest.predict(X_test)
_classification_metrics(y_test, preds_forest)
```

```
Confusion Matrix
[[61 32]
 [42 68]]

Classification Report
              precision    recall  f1-score   support

           0       0.68      0.62      0.65       110
           1       0.59      0.66      0.62        93

    accuracy                           0.64       203
   macro avg       0.64      0.64      0.64       203
weighted avg       0.64      0.64      0.64       203
```

In [8]:
```
# Boosted
model_boost = GradientBoostingClassifier()
model_boost.fit(X_train, y_train)
preds_boost = model_boost.predict(X_test)
_classification_metrics(y_test, preds_boost)
```

```
Confusion Matrix
[[64 29]
 [40 70]]

Classification Report
              precision    recall  f1-score   support

           0       0.71      0.64      0.67       110
           1       0.62      0.69      0.65        93

    accuracy                           0.66       203
   macro avg       0.66      0.66      0.66       203
weighted avg       0.67      0.66      0.66       203
```

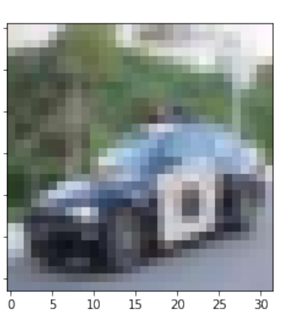
In [9]:
```
# attempt to improve best overal classifier
def svc_gridsearch(c_list, kernel_list):
    model_svc = SVC()
    grid_svc = GridSearchCV(
        model_svc,
        param_grid = {'C':c_list, 'kernel':kernel_list},
        scoring = 'roc_auc')
    return grid_svc.fit(X_train, y_train)

# search parameters
C_LIST = [.5, 1.5]
KERNEL_LIST = ['rbf', 'sigmoid']

# commented out so the pdf generates
grid_svc = svc_gridsearch(C_LIST, KERNEL_LIST)

# returns a best model of c=1.5 and kernel=rbf
print(grid_svc.best_params_)

preds_svc_best = grid_svc.predict(X_test)
_classification_metrics(y_test, preds_svc_best)
```

```
{'C': 1.5, 'kernel': 'rbf'}
Confusion Matrix
[[66 27]
 [37 73]]

Classification Report
              precision    recall  f1-score   support

           0       0.73      0.66      0.70       110
           1       0.64      0.71      0.67        93

    accuracy                           0.68       203
   macro avg       0.69      0.69      0.68       203
weighted avg       0.69      0.68      0.69       203
```

Neural Net Classifiers

In [10]:
```
# re-import image data
X_train, y_train, X_valid, y_valid, X_test, y_test = _get_cifar()

# show an example image
supress = plt.imshow(X_train[1])
```

```
X_train shape: (536, 32, 32, 3)
y_train shape: (536, 1)
X_valid shape: (537, 32, 32, 3)
y_valid shape: (537, 1)
X_test shape: (226, 32, 32, 3)
y_test shape: (226, 1)
```



In [11]:
```
# cnn model 1
model_cnn_1 = Sequential([
    Conv2D(16, kernel_size=(3,3), activation='relu', padding='same', input_shape=(32,32,3)),
    MaxPooling2D(pool_size=(4, 4), strides=4),
    Flatten(),
    Dense(2, activation='softmax')
])

model_cnn_1.compile(
    optimizer='adam',
    loss=tf.keras.losses.SparseCategoricalCrossentropy(from_logits=True),
    metrics=['accuracy'])

model_cnn_1.fit(
    X_train,
    y_train,
    epochs=10,
    batch_size=20,
    validation_data=(X_valid, y_valid),
    verbose=False)

model_cnn_1.evaluate(X_test, y_test)
```

```
8/8 [==============================] - 0s 2ms/step - loss: 2.9975 - accuracy: 0.7345
```

Out[11]:
```
[2.997479200363159, 0.7345132827758789]
```

In [12]:
```
# look at model 1 predictive performance
preds_cnn_1 = model_cnn_1.predict(X_test, verbose=0)
_classification_metrics(y_test, _prob_to_pred(preds_cnn_1))
```

```
Confusion Matrix
[[83 24]
 [36 83]]

Classification Report
              precision    recall  f1-score   support

           0       0.78      0.70      0.73       119
           1       0.70      0.78      0.73       107

    accuracy                           0.73       226
   macro avg       0.74      0.74      0.73       226
weighted avg       0.74      0.73      0.73       226
```

In [13]:
```
# attempt to improve performance with model 2
model_cnn_2 = Sequential([
    Conv2D(64, kernel_size=(3,3), activation='relu', strides=(1,1), kernel_regularizer=keras.regularizers.l1_l2(.001),
padding='same', input_shape=(32,32,3)),
    MaxPooling2D(pool_size=(6, 6), strides=2),
    Flatten(),
    Dense(40, activation='softmax')
])

model_cnn_2.compile(
    optimizer='adam',
    loss=tf.keras.losses.SparseCategoricalCrossentropy(from_logits=True),
    metrics=['accuracy'])

model_cnn_2.fit(
    X_train,
    y_train,
    epochs=10,
    batch_size=20,
    validation_data=(X_valid, y_valid),
    verbose=False)

model_cnn_2.evaluate(X_test, y_test)
```

```
8/8 [==============================] - 0s 4ms/step - loss: 2.0348 - accuracy: 0.7434
```

Out[13]:
```
[2.0348005294799805, 0.7433628439903259]
```

In [14]:
```
# look at model 2 predictive performance
preds_cnn_2 = model_cnn_2.predict(X_test, verbose=0)
_classification_metrics(y_test, _prob_to_pred(preds_cnn_2))
```

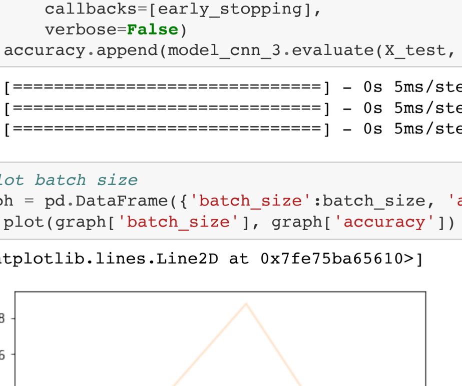
```
Confusion Matrix
[[83 24]
 [34 85]]

Classification Report
              precision    recall  f1-score   support

           0       0.78      0.71      0.75       119
           1       0.71      0.78      0.74       107

    accuracy                           0.74       226
   macro avg       0.74      0.74      0.74       226
weighted avg       0.75      0.74      0.74       226
```

In [15]:
```
# further optimization with model 3
model_cnn_3 = Sequential([
    Conv2D(64, kernel_size=(3,3), activation='relu', kernel_regularizer=keras.regularizers.l1_l2(.001), padding='same'
, input_shape=(32,32,3)),
    MaxPooling2D((2, 2)),
    Conv2D(64, (3, 3), activation='relu'),
    MaxPooling2D((2, 2)),
    Conv2D(64, (3, 3), activation='relu'),
    Flatten(),
    Dense(64, activation='relu'),
    Dropout(rate=.5),
    Dense(2)
])

# define callback
early_stopping = EarlyStopping(monitor='val_loss', patience=10)

model_cnn_3.compile(
    optimizer='adam',
    loss=tf.keras.losses.SparseCategoricalCrossentropy(from_logits=True),
    metrics=['accuracy'])

# use reduced list for document creation
#batch_size = [50,55,60,65,70,75,80,85,90,95,100,105,110,115,120,125,130,135,140,145,150,155]
batch_size = [50, 110, 155]
accuracy = []
for b_ in batch_size:
    history = model_cnn_3.fit(
        X_train,
        y_train,
        epochs=100,
        batch_size=b_,
        validation_data=(X_valid, y_valid),
        callbacks=[early_stopping],
        verbose=False)
    accuracy.append(model_cnn_3.evaluate(X_test, y_test)[1])
```

```
8/8 [==============================] - 0s 5ms/step - loss: 0.7839 - accuracy: 0.7655
8/8 [==============================] - 0s 5ms/step - loss: 0.7539 - accuracy: 0.7788
8/8 [==============================] - 0s 5ms/step - loss: 0.9207 - accuracy: 0.7655
```

In [16]:
```
# plot batch size
graph = pd.DataFrame({'batch_size':batch_size, 'accuracy':accuracy})
plt.plot(graph['batch_size'], graph['accuracy'])
```

Out[16]:
```
[<matplotlib.lines.Line2D at 0x7fe75ba65610>]
```



In [17]:
```
# optimum batch size found to be 110
best_batch = graph['batch_size'].loc[graph['accuracy'] == max(graph['accuracy'])]
best_batch
```

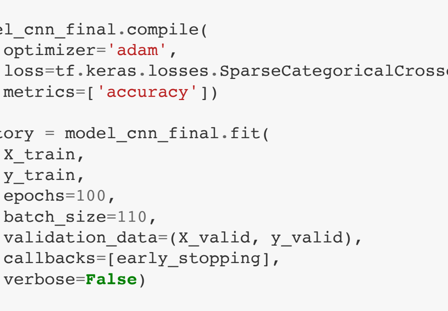
Out[17]:
```
1    110
Name: batch_size, dtype: int64
```

In [18]:
```
# run a final model
model_cnn_final = Sequential([
    Conv2D(64, kernel_size=(3,3), activation='relu', kernel_regularizer=keras.regularizers.l1_l2(.001), padding='same'
, input_shape=(32,32,3)),
    MaxPooling2D((2, 2)),
    Conv2D(64, (3, 3), activation='relu'),
    MaxPooling2D((2, 2)),
    Conv2D(64, (3, 3), activation='relu'),
    Flatten(),
    Dense(64, activation='relu'),
    Dropout(rate=.5),
    Dense(2)
])

model_cnn_final.compile(
    optimizer='adam',
    loss=tf.keras.losses.SparseCategoricalCrossentropy(from_logits=True),
    metrics=['accuracy'])

history = model_cnn_final.fit(
    X_train,
    y_train,
    epochs=100,
    batch_size=110,
    validation_data=(X_valid, y_valid),
    callbacks=[early_stopping],
    verbose=False)

model_cnn_final.evaluate(X_test, y_test)
```

```
8/8 [==============================] - 0s 6ms/step - loss: 0.7453 - accuracy: 0.7522
```

Out[18]:
```
[0.7453163862228394, 0.752212405204773]
```

In [19]:
```
# plot accuracy over epochs
plt.plot(history.history['accuracy'], label='Training accuracy')
plt.plot(history.history['val_accuracy'], label='Validation accuracy')
suppress = plt.legend()
```



In [20]:
```
# look at final model predictive performance
preds_cnn_final = model_cnn_final.predict(X_test, verbose=0)
_classification_metrics(y_test, _prob_to_pred(preds_cnn_final))
```

```
Confusion Matrix
[[84 23]
 [33 86]]

Classification Report
              precision    recall  f1-score   support

           0       0.79      0.72      0.75       119
           1       0.72      0.79      0.75       107

    accuracy                           0.75       226
   macro avg       0.75      0.75      0.75       226
weighted avg       0.76      0.75      0.75       226
```

In [ ]: