Importing Necessary Libraries

```
import random
import numpy as np
from tensorflow.keras.datasets import cifar10
import matplotlib.pyplot as plt
from sklearn.decomposition import PCA
from sklearn.metrics import accuracy_score, precision_score, recall_score, f1_score, classification_report

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

Loading the dataset

```
import tensorflow as tf
from keras.datasets import cifar10
from tensorflow.keras.utils import to_categorical

# Load the CIFAR-10 dataset
(train_images, train_labels), (test_images, test_labels) = cifar10.load_data()

# Preprocess the data
train_images = train_images.astype('float32') / 255.0
test_images = test_images.astype('float32') / 255.0
train_labels = to_categorical(train_labels)
test_labels = to_categorical(test_labels)
```

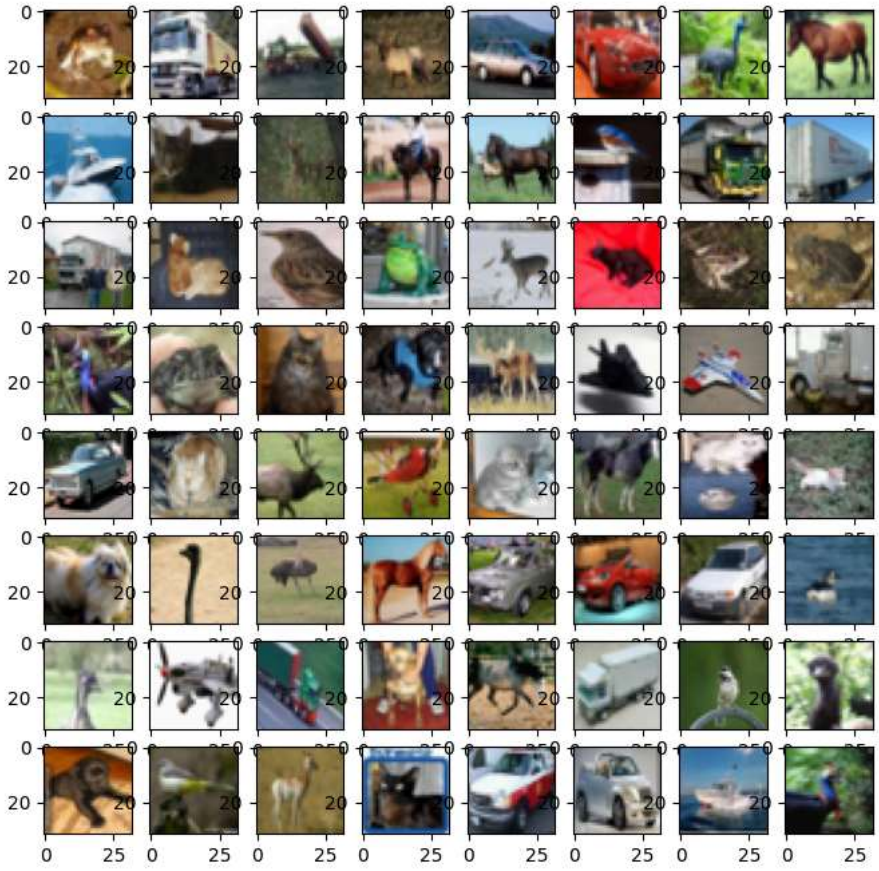
```
Downloading data from https://www.cs.toronto.edu/~kriz/cifar-10-python.tar.gz
170498071/170498071 [==============================] - 4s 0us/step
```

```
# Checking the sjize of the test dataset
test_images.shape
```

```
(10000, 32, 32, 3)
```

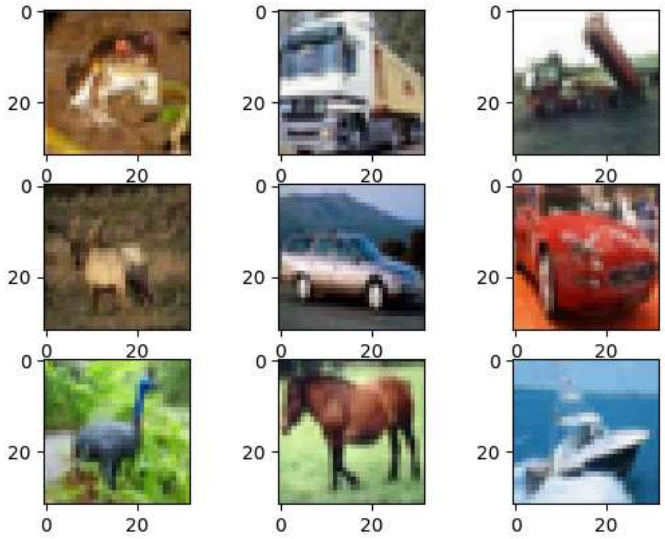
Checking some of the images loaded in our dataset

```
fig = plt.figure(figsize = (8,8))
for i in range(64):
    ax = fig.add_subplot(8,8,i+1)
    ax.imshow(train_images[i],cmap=plt.cm.bone)
plt.show()
```



```
# example of loading the cifar10 dataset
from matplotlib import pyplot
from keras.datasets import cifar10
# load dataset
(trainX, trainy), (testX, testy) = cifar10.load_data()
# summarize loaded dataset
print('Train: X=%s, y=%s' % (trainX.shape, trainy.shape))
print('Test: X=%s, y=%s' % (testX.shape, testy.shape))
# plot first few images
for i in range(9):
    # define subplot
    pyplot.subplot(330 + 1 + i)
    # plot raw pixel data
    pyplot.imshow(trainX[i])
# show the figure
pyplot.show()
```

```
Train: X=(50000, 32, 32, 3), y=(50000, 1)
Test: X=(10000, 32, 32, 3), y=(10000, 1)
```



Our Image initially having (50000, 32x32x3) is reshaped to (50000 x 3072) dimensions, for further analysis

```
x_train = trainX.reshape(train_images.shape[0],-1)
x_test = testX.reshape(test_images.shape[0], -1)
```

```
x_train.shape
```

```
(50000, 3072)
```

We use Robust Scaler to scale the dataset. Robust Scaler is considered to be more robust to outliers

```
from sklearn.preprocessing import StandardScaler, RobustScaler
sc = RobustScaler()
x_train_scaled = sc.fit_transform(x_train)
```

```
x_test_scaled = sc.transform(x_test)
```

```
y_train = trainy
y_test = testy
```

```
# pca = PCA()
# pca.fit_transform(x_train_scaled)
```

```
# k = 0
# total = sum(pca.explained_variance_)
# current_sum = 0

# while(current_sum / total < 0.99):
#     current_sum += pca.explained_variance_[k]
#     k += 1
# k
```

```
# pca_cifar = PCA(n_components=k,whiten=True)
# x_train_pca_cifar = pca_cifar.fit_transform(x_train_scaled)
# x_test_pca_cifar = pca_cifar.transform(x_test_scaled)
```

```
# x_test_pca_cifar.shape
```

```
# y_train.shape
```

Let us now fit model and check for evaluation metrics

```
from sklearn.linear_model import LogisticRegression
lr = LogisticRegression()
lr.fit(x_train_scaled, y_train.ravel())
```

```
LogisticRegression()
```

```
y_pred_lr = lr.predict(x_test_scaled)
logistic_regression_score = accuracy_score(y_test, y_pred_lr)
logistic_regression_score
```

```
0.4014
```

```
from sklearn.metrics import precision_score, recall_score, f1_score, classification_report

y_pred_lr = lr.predict(x_test_scaled)

precision = precision_score(y_test, y_pred_lr, average = 'weighted')
recall = recall_score(y_test, y_pred_lr, average = 'weighted')
f1 = f1_score(y_test, y_pred_lr, average = 'weighted')

classification_rep = classification_report(y_test, y_pred_lr)

print("Precision:", precision)
print("Recall:", recall)
print("F1 Score:", f1)
print("Classification Report:\n", classification_rep)
```

```
Precision: 0.3985215429260664
Recall: 0.4014
F1 Score: 0.3991216365736525
Classification Report:
               precision    recall  f1-score   support

           0       0.46      0.48      0.47      1000
           1       0.47      0.48      0.47      1000
           2       0.32      0.28      0.30      1000
           3       0.28      0.27      0.27      1000
           4       0.36      0.30      0.33      1000
           5       0.33      0.34      0.33      1000
           6       0.39      0.45      0.42      1000
           7       0.45      0.43      0.44      1000
           8       0.49      0.53      0.51      1000
           9       0.44      0.46      0.45      1000

    accuracy                           0.40     10000
   macro avg       0.40      0.40      0.40     10000
weighted avg       0.40      0.40      0.40     10000
```

```
from sklearn.metrics import confusion_matrix

conf_matrix = confusion_matrix(y_test, y_pred_lr)

print("Confusion Matrix:")
print(conf_matrix)
```

```
Confusion Matrix:
[[484  41  53  41  20  27  25  51 182  76]
 [ 52 478  31  39  28  40  41  44  78 169]
 [ 97  39 280 105 119  82 131  76  47  24]
 [ 38  50  93 267  61 195 144  54  37  61]
 [ 56  24 137  69 297  92 168 105  26  26]
 [ 40  46  96 172  88 337  89  68  36  28]
 [ 22  41  75 144  91  97 453  36  16  25]
 [ 53  48  66  71  94  87  43 428  31  79]
 [154  72  28  28  12  38  18  22 529  99]
 [ 65 178  19  30  17  27  47  60  96 461]]
```

```
from sklearn.ensemble import RandomForestClassifier
```

```
rf_classifier = RandomForestClassifier(n_estimators = 50)

rf_classifier.fit(x_train_scaled, y_train.ravel())
```

```
RandomForestClassifier
RandomForestClassifier(n_estimators=50)
```

```
y_pred_rf = rf_classifier.predict(x_test_scaled)
rf_classifier_score = accuracy_score(y_test, y_pred_rf)
rf_classifier_score
```

```
0.4508
```

```
from sklearn.metrics import accuracy_score, precision_score, recall_score, f1_score, classification_report, confusion_matrix

y_pred_rf = rf_classifier.predict(x_test_scaled)

accuracy_rf = accuracy_score(y_test, y_pred_rf)
precision_rf = precision_score(y_test, y_pred_rf, average = 'weighted')
recall_rf = recall_score(y_test, y_pred_rf, average = 'weighted')
f1_rf = f1_score(y_test, y_pred_rf, average = 'weighted')
classification_rep_rf = classification_report(y_test, y_pred_rf)
conf_matrix_rf = confusion_matrix(y_test, y_pred_rf)

print("Random Forest Classifier Metrics:")
print("Accuracy:", accuracy_rf)
print("Precision:", precision_rf)
print("Recall:", recall_rf)
print("F1 Score:", f1_rf)
print("Classification Report:\n", classification_rep_rf)
print("Confusion Matrix:")
print(conf_matrix_rf)
```

```
Random Forest Classifier Metrics:
Accuracy: 0.4508
Precision: 0.4465691128922581
Recall: 0.4508
F1 Score: 0.44759177397875494
Classification Report:
               precision    recall  f1-score   support

           0       0.52      0.57      0.54      1000
           1       0.50      0.54      0.52      1000
           2       0.33      0.32      0.33      1000
           3       0.31      0.25      0.28      1000
           4       0.38      0.38      0.38      1000
           5       0.42      0.38      0.40      1000
           6       0.47      0.53      0.50      1000
           7       0.48      0.42      0.45      1000
           8       0.59      0.59      0.59      1000
           9       0.47      0.52      0.49      1000

    accuracy                           0.45     10000
   macro avg       0.45      0.45      0.45     10000
weighted avg       0.45      0.45      0.45     10000

Confusion Matrix:
[[566  39  63  24  30  20  21  24 156  57]
 [ 43 542  24  38  28  31  30  34  54 176]
 [116  37 320  76 163  64 107  58  26  33]
 [ 59  40  90 254  83 185 135  71  27  56]
 [ 45  30 162  52 384  50 142  83  29  23]
 [ 31  39  91 168  80 380  80  78  23  30]
 [ 18  35 107  72 107  57 530  34   5  35]
 [ 47  45  71  71 105  78  48 422  19  94]
 [113  87  20  33  20  23  11  23 592  78]
 [ 54 185  15  36  20  16  33  44  79 518]]
```

This time we check for a validation set of 20-80. We do this for one model i.e, Logistic Regression

```
from sklearn.model_selection import train_test_split
from sklearn.linear_model import LogisticRegression
from sklearn.metrics import accuracy_score, precision_score, recall_score, f1_score

# Split the data into training and testing sets
x_val_train, x_val_test, y_val_train, y_val_test = train_test_split(x_train, y_train, test_size=0.2, random_state=42)

# Fit the model
logreg = LogisticRegression()
logreg.fit(x_val_train, y_val_train)

# Make predictions
y_val_pred = logreg.predict(x_val_test)

# Calculate evaluation metrics
accuracy_val = accuracy_score(y_val_test, y_val_pred)
precision_val = precision_score(y_val_test, y_val_pred, average = 'macro')
recall_val = recall_score(y_val_test, y_val_pred, average = 'macro')
f1_val = f1_score(y_val_test, y_val_pred, average = 'macro')

print("Accuracy:", accuracy_val)
print("Precision:", precision_val)
print("Recall:", recall_val)
print("F1 Score:", f1_val)
```

```
Accuracy: 0.4045
Precision: 0.3990480934172669
Recall: 0.40461833231965516
F1 Score: 0.4001986792394578
```

Applying Cross - validation with different k values. Choosing only logistic regression model for comparison to reduce computational intensivity

For k=3

```
from sklearn.model_selection import cross_val_score, KFold
from sklearn.linear_model import LogisticRegression
from sklearn.metrics import accuracy_score, precision_score, recall_score, f1_score

# Create a logistic regression model
logreg = LogisticRegression()

# Perform 5-fold cross-validation
cv = KFold(n_splits=3, shuffle=True, random_state=42)

# Calculate evaluation metrics using cross-validation
accuracy_val = cross_val_score(logreg, x_train, y_train, cv=cv, scoring='accuracy').mean()
# precision_val = cross_val_score(logreg, x_train, y_train, cv=cv, scoring='precision_macro').mean()
# recall_val = cross_val_score(logreg, x_train, y_train, cv=cv, scoring='recall_macro').mean()
# f1_val = cross_val_score(logreg, x_train, y_train, cv=cv, scoring='f1_macro').mean()

print("Accuracy:", accuracy_val)
print("Precision:", precision_val)
print("Recall:", recall_val)
print("F1 Score:", f1_val)
```

```
Accuracy: 0.40174007392287053
Precision: 0.3990480934172669
Recall: 0.40461833231965516
F1 Score: 0.4001986792394578
```

For k=5

```
from sklearn.model_selection import cross_val_score, KFold
from sklearn.linear_model import LogisticRegression
from sklearn.metrics import accuracy_score, precision_score, recall_score, f1_score

# Create a logistic regression model
logreg = LogisticRegression()

# Perform 5-fold cross-validation
cv = KFold(n_splits=5, shuffle=True, random_state=42)

# Calculate evaluation metrics using cross-validation
accuracy_val = cross_val_score(logreg, x_train, y_train, cv=cv, scoring='accuracy').mean()
# precision_val = cross_val_score(logreg, x_train, y_train, cv=cv, scoring='precision_macro').mean()
# recall_val = cross_val_score(logreg, x_train, y_train, cv=cv, scoring='recall_macro').mean()
# f1_val = cross_val_score(logreg, x_train, y_train, cv=cv, scoring='f1_macro').mean()

print("Accuracy:", accuracy_val)
# print("Precision:", precision_val)
# print("Recall:", recall_val)
# print("F1 Score:", f1_val)
```

```
Accuracy: 0.40546
Precision: 0.3990480934172669
Recall: 0.40461833231965516
F1 Score: 0.4001986792394578
```

For k = 10

```
from sklearn.model_selection import cross_val_score, KFold
from sklearn.linear_model import LogisticRegression
from sklearn.metrics import accuracy_score, precision_score, recall_score, f1_score

# Create a logistic regression model
logreg = LogisticRegression()

# Perform 5-fold cross-validation
cv = KFold(n_splits=10, shuffle=True, random_state=42)

# Calculate evaluation metrics using cross-validation
accuracy_val = cross_val_score(logreg, x_train, y_train, cv=cv, scoring='accuracy').mean()
# precision_val = cross_val_score(logreg, x_train, y_train, cv=cv, scoring='precision_macro').mean()
# recall_val = cross_val_score(logreg, x_train, y_train, cv=cv, scoring='recall_macro').mean()
# f1_val = cross_val_score(logreg, x_train, y_train, cv=cv, scoring='f1_macro').mean()

print("Accuracy:", accuracy_val)
# print("Precision:", precision_val)
# print("Recall:", recall_val)
# print("F1 Score:", f1_val)
```

```
Accuracy: 0.40574000000000005
Precision: 0.3990480934172669
Recall: 0.40461833231965516
F1 Score: 0.4001986792394578
```

As a part 2 of our problem, we repeat the same experiment on grayscale images this time.

```
import numpy as np
import tensorflow as tf

# Load CIFAR-10 dataset
(x_train, y_train), (x_test, y_test) = tf.keras.datasets.cifar10.load_data()

# Convert images to grayscale
x_train_gray = np.mean(x_train, axis=3)
x_test_gray = np.mean(x_test, axis=3)

# Add a single channel dimension
x_train_gray = np.reshape(x_train_gray, x_train_gray.shape + (1,))
x_test_gray = np.reshape(x_test_gray, x_test_gray.shape + (1,))

# Normalize pixel values to the range [0, 1]
x_train_gray = x_train_gray.astype('float32') / 255.0
x_test_gray = x_test_gray.astype('float32') / 255.0

# Flatten the images
x_train_f = x_train_gray.reshape(x_train_gray.shape[0], -1)
```

```
from sklearn.linear_model import LogisticRegression
lr = LogisticRegression()
lr.fit(x_train, y_train.ravel())
```

▾ LogisticRegression

LogisticRegression()

```
from sklearn.metrics import precision_score, recall_score, f1_score, classification_report

y_pred_lr = lr.predict(x_test)

precision = precision_score(y_test, y_pred_lr, average = 'weighted')
recall = recall_score(y_test, y_pred_lr, average = 'weighted')
f1 = f1_score(y_test, y_pred_lr, average = 'weighted')

classification_rep = classification_report(y_test, y_pred_lr)

print("Precision:", precision)
print("Recall:", recall)
print("F1 Score:", f1)
print("Classification Report:\n", classification_rep)
```

```
Precision: 0.3057978481452976
Recall: 0.3124
F1 Score: 0.3077123775021974
Classification Report:
               precision    recall  f1-score   support

            0       0.34      0.36      0.35      1000
            1       0.37      0.39      0.38      1000
            2       0.24      0.20      0.22      1000
            3       0.22      0.16      0.19      1000
            4       0.25      0.22      0.24      1000
            5       0.32      0.32      0.32      1000
            6       0.29      0.31      0.30      1000
            7       0.30      0.30      0.30      1000
            8       0.34      0.40      0.37      1000
            9       0.38      0.45      0.42      1000

     accuracy                           0.31     10000
    macro avg       0.31      0.31      0.31     10000
 weighted avg       0.31      0.31      0.31     10000
```

```
rf = RandomForestClassifier()
rf.fit(x_train, y_train.ravel())
```

▾ RandomForestClassifier

RandomForestClassifier()