

Test Notebook

Problem 1 Test Set Evaluation

```
In [2]: import tensorflow as tf
from tensorflow import keras
import numpy as np
import matplotlib.pyplot as plt
import pandas as pd
from PIL import Image
import cv2

# Load test set and labels
X_test = np.load('flower_species_classification/data_test.npy').T
t_test = np.load('flower_species_classification/labels_test.npy')

X_test.shape, t_test.shape
```

```
Out[2]: ((415, 270000), (415,))
```

```
In [7]: # convert numpy arrays for tensorflow

X_test_rs = tf.constant(X_test.reshape((X_test.shape[0], 300, 300, 3)),
                        dtype=tf.float32)

X_test_rs.shape, t_test.shape
```

```
Out[7]: (TensorShape([415, 300, 300, 3]), (415,))
```

Loading trained model from Problem 1

```
In [4]: import joblib

model_p1 = joblib.load('trained_models/Q1_trainedModel.pkl');
```

```
Keras model archive loading:  
File Name                                Modified      Size  
config.json                               2022-12-09 22:29:34    77229  
metadata.json                            2022-12-09 22:29:34      64  
variables.h5                             2022-12-09 22:29:34  250627128  
Keras weights file (<HDF5 file "variables.h5" (mode r)>) loading:  
...layers\dense  
.....vars  
.....0  
.....1  
...layers\functional  
.....vars  
...layers\functional\layers\activation  
.....vars  
...layers\functional\layers\activation_1  
.....vars  
...layers\functional\layers\activation_10  
.....vars  
...layers\functional\layers\activation_11  
.....vars  
...layers\functional\layers\activation_12  
.....vars  
...layers\functional\layers\activation_13  
.....vars  
...layers\functional\layers\activation_14  
.....vars  
...layers\functional\layers\activation_15  
.....vars  
...layers\functional\layers\activation_16  
.....vars  
...layers\functional\layers\activation_17  
.....vars  
...layers\functional\layers\activation_18  
.....vars  
...layers\functional\layers\activation_19  
.....vars  
...layers\functional\layers\activation_2  
.....vars  
...layers\functional\layers\activation_20  
.....vars  
...layers\functional\layers\activation_21  
.....vars  
...layers\functional\layers\activation_22  
.....vars  
...layers\functional\layers\activation_23  
.....vars  
...layers\functional\layers\activation_24  
.....vars  
...layers\functional\layers\activation_25  
.....vars  
...layers\functional\layers\activation_26  
.....vars  
...layers\functional\layers\activation_27  
.....vars  
...layers\functional\layers\activation_28  
.....vars  
...layers\functional\layers\activation_29  
.....vars  
...layers\functional\layers\activation_3  
.....vars
```

```
...layers\functional\layers\activation_30
.....vars
...layers\functional\layers\activation_31
.....vars
...layers\functional\layers\activation_32
.....vars
...layers\functional\layers\activation_33
.....vars
...layers\functional\layers\activation_34
.....vars
...layers\functional\layers\activation_4
.....vars
...layers\functional\layers\activation_5
.....vars
...layers\functional\layers\activation_6
.....vars
...layers\functional\layers\activation_7
.....vars
...layers\functional\layers\activation_8
.....vars
...layers\functional\layers\activation_9
.....vars
...layers\functional\layers\add
.....vars
...layers\functional\layers\add_1
.....vars
...layers\functional\layers\add_10
.....vars
...layers\functional\layers\add_11
.....vars
...layers\functional\layers\add_2
.....vars
...layers\functional\layers\add_3
.....vars
...layers\functional\layers\add_4
.....vars
...layers\functional\layers\add_5
.....vars
...layers\functional\layers\add_6
.....vars
...layers\functional\layers\add_7
.....vars
...layers\functional\layers\add_8
.....vars
...layers\functional\layers\add_9
.....vars
...layers\functional\layers\batch_normalization
.....vars
.....0
.....1
.....2
.....3
...layers\functional\layers\batch_normalization_1
.....vars
.....0
.....1
.....2
.....3
...layers\functional\layers\batch_normalization_10
.....vars
```

```
.....0
.....1
.....2
.....3
...layers\functional\layers\batch_normalization_11
.....vars
.....0
.....1
.....2
.....3
...layers\functional\layers\batch_normalization_12
.....vars
.....0
.....1
.....2
.....3
...layers\functional\layers\batch_normalization_13
.....vars
.....0
.....1
.....2
.....3
...layers\functional\layers\batch_normalization_14
.....vars
.....0
.....1
.....2
.....3
...layers\functional\layers\batch_normalization_15
.....vars
.....0
.....1
.....2
.....3
...layers\functional\layers\batch_normalization_16
.....vars
.....0
.....1
.....2
.....3
...layers\functional\layers\batch_normalization_17
.....vars
.....0
.....1
.....2
.....3
...layers\functional\layers\batch_normalization_18
.....vars
.....0
.....1
.....2
.....3
...layers\functional\layers\batch_normalization_19
.....vars
.....0
.....1
.....2
.....3
...layers\functional\layers\batch_normalization_2
.....vars
```

```
.....0
.....1
.....2
.....3
...layers\functional\layers\batch_normalization_20
.....vars
.....0
.....1
.....2
.....3
...layers\functional\layers\batch_normalization_21
.....vars
.....0
.....1
.....2
.....3
...layers\functional\layers\batch_normalization_22
.....vars
.....0
.....1
.....2
.....3
...layers\functional\layers\batch_normalization_23
.....vars
.....0
.....1
.....2
.....3
...layers\functional\layers\batch_normalization_24
.....vars
.....0
.....1
.....2
.....3
...layers\functional\layers\batch_normalization_25
.....vars
.....0
.....1
.....2
.....3
...layers\functional\layers\batch_normalization_26
.....vars
.....0
.....1
.....2
.....3
...layers\functional\layers\batch_normalization_27
.....vars
.....0
.....1
.....2
.....3
...layers\functional\layers\batch_normalization_28
.....vars
.....0
.....1
.....2
.....3
...layers\functional\layers\batch_normalization_29
.....vars
```

```
.....0
.....1
.....2
.....3
...layers\functional\layers\batch_normalization_3
.....vars
.....0
.....1
.....2
.....3
...layers\functional\layers\batch_normalization_30
.....vars
.....0
.....1
.....2
.....3
...layers\functional\layers\batch_normalization_31
.....vars
.....0
.....1
.....2
.....3
...layers\functional\layers\batch_normalization_32
.....vars
.....0
.....1
.....2
.....3
...layers\functional\layers\batch_normalization_33
.....vars
.....0
.....1
.....2
.....3
...layers\functional\layers\batch_normalization_34
.....vars
.....0
.....1
.....2
.....3
...layers\functional\layers\batch_normalization_35
.....vars
.....0
.....1
.....2
.....3
...layers\functional\layers\batch_normalization_36
.....vars
.....0
.....1
.....2
.....3
...layers\functional\layers\batch_normalization_37
.....vars
.....0
.....1
.....2
.....3
...layers\functional\layers\batch_normalization_38
.....vars
```

```
.....0
.....1
.....2
.....3
...layers\functional\layers\batch_normalization_39
.....vars
.....0
.....1
.....2
.....3
...layers\functional\layers\batch_normalization_4
.....vars
.....0
.....1
.....2
.....3
...layers\functional\layers\batch_normalization_5
.....vars
.....0
.....1
.....2
.....3
...layers\functional\layers\batch_normalization_6
.....vars
.....0
.....1
.....2
.....3
...layers\functional\layers\batch_normalization_7
.....vars
.....0
.....1
.....2
.....3
...layers\functional\layers\batch_normalization_8
.....vars
.....0
.....1
.....2
.....3
...layers\functional\layers\batch_normalization_9
.....vars
.....0
.....1
.....2
.....3
...layers\functional\layers\conv2d
.....vars
.....0
...layers\functional\layers\conv2d_1
.....vars
.....0
...layers\functional\layers\conv2d_2
.....vars
.....0
...layers\functional\layers\conv2d_3
.....vars
.....0
...layers\functional\layers\conv2d_4
.....vars
```

```
.....0
...layers\functional\layers\conv2d_5
.....vars
.....0
...layers\functional\layers\input_layer
.....vars
...layers\functional\layers\max_pooling2d
.....vars
...layers\functional\layers\max_pooling2d_1
.....vars
...layers\functional\layers\max_pooling2d_2
.....vars
...layers\functional\layers\max_pooling2d_3
.....vars
...layers\functional\layers\separable_conv2d
.....vars
.....0
.....1
...layers\functional\layers\separable_conv2d_1
.....vars
.....0
.....1
...layers\functional\layers\separable_conv2d_10
.....vars
.....0
.....1
...layers\functional\layers\separable_conv2d_11
.....vars
.....0
.....1
...layers\functional\layers\separable_conv2d_12
.....vars
.....0
.....1
...layers\functional\layers\separable_conv2d_13
.....vars
.....0
.....1
...layers\functional\layers\separable_conv2d_14
.....vars
.....0
.....1
...layers\functional\layers\separable_conv2d_15
.....vars
.....0
.....1
...layers\functional\layers\separable_conv2d_16
.....vars
.....0
.....1
...layers\functional\layers\separable_conv2d_17
.....vars
.....0
.....1
...layers\functional\layers\separable_conv2d_18
.....vars
.....0
.....1
...layers\functional\layers\separable_conv2d_19
.....vars
```

```
.....0  
.....1  
...layers\functional\layers\separable_conv2d_2  
.....vars  
.....0  
.....1  
...layers\functional\layers\separable_conv2d_20  
.....vars  
.....0  
.....1  
...layers\functional\layers\separable_conv2d_21  
.....vars  
.....0  
.....1  
...layers\functional\layers\separable_conv2d_22  
.....vars  
.....0  
.....1  
...layers\functional\layers\separable_conv2d_23  
.....vars  
.....0  
.....1  
...layers\functional\layers\separable_conv2d_24  
.....vars  
.....0  
.....1  
...layers\functional\layers\separable_conv2d_25  
.....vars  
.....0  
.....1  
...layers\functional\layers\separable_conv2d_26  
.....vars  
.....0  
.....1  
...layers\functional\layers\separable_conv2d_27  
.....vars  
.....0  
.....1  
...layers\functional\layers\separable_conv2d_28  
.....vars  
.....0  
.....1  
...layers\functional\layers\separable_conv2d_29  
.....vars  
.....0  
.....1  
...layers\functional\layers\separable_conv2d_3  
.....vars  
.....0  
.....1  
...layers\functional\layers\separable_conv2d_30  
.....vars  
.....0  
.....1  
...layers\functional\layers\separable_conv2d_31  
.....vars  
.....0  
.....1  
...layers\functional\layers\separable_conv2d_32  
.....vars
```

```
.....0
.....1
...layers\functional\layers\separable_conv2d_33
.....vars
.....0
.....1
...layers\functional\layers\separable_conv2d_4
.....vars
.....0
.....1
...layers\functional\layers\separable_conv2d_5
.....vars
.....0
.....1
...layers\functional\layers\separable_conv2d_6
.....vars
.....0
.....1
...layers\functional\layers\separable_conv2d_7
.....vars
.....0
.....1
...layers\functional\layers\separable_conv2d_8
.....vars
.....0
.....1
...layers\functional\layers\separable_conv2d_9
.....vars
.....0
.....1
...layers\global_average_pooling2d
.....vars
...layers\input_layer
.....vars
...layers\resizing
.....vars
...metrics\mean
.....vars
.....0
.....1
...metrics\mean_metric_wrapper
.....vars
.....0
.....1
...optimizer
.....vars
.....0
.....1
.....10
.....100
.....101
.....102
.....103
.....104
.....105
.....106
.....107
.....108
.....109
.....11
```

.....110
.....111
.....112
.....113
.....114
.....115
.....116
.....117
.....118
.....119
.....12
.....120
.....121
.....122
.....123
.....124
.....125
.....126
.....127
.....128
.....129
.....13
.....130
.....131
.....132
.....133
.....134
.....135
.....136
.....137
.....138
.....139
.....14
.....140
.....141
.....142
.....143
.....144
.....145
.....146
.....147
.....148
.....149
.....15
.....150
.....151
.....152
.....153
.....154
.....155
.....156
.....157
.....158
.....159
.....16
.....160
.....161
.....162
.....163
.....164

.....165
.....166
.....167
.....168
.....169
.....17
.....170
.....171
.....172
.....173
.....174
.....175
.....176
.....177
.....178
.....179
.....18
.....180
.....181
.....182
.....183
.....184
.....185
.....186
.....187
.....188
.....189
.....19
.....190
.....191
.....192
.....193
.....194
.....195
.....196
.....197
.....198
.....199
.....2
.....20
.....200
.....201
.....202
.....203
.....204
.....205
.....206
.....207
.....208
.....209
.....21
.....210
.....211
.....212
.....213
.....214
.....215
.....216
.....217
.....218

..... 219
..... 22
..... 220
..... 221
..... 222
..... 223
..... 224
..... 225
..... 226
..... 227
..... 228
..... 229
..... 23
..... 230
..... 231
..... 232
..... 233
..... 234
..... 235
..... 236
..... 237
..... 238
..... 239
..... 24
..... 240
..... 241
..... 242
..... 243
..... 244
..... 245
..... 246
..... 247
..... 248
..... 249
..... 25
..... 250
..... 251
..... 252
..... 253
..... 254
..... 255
..... 256
..... 257
..... 258
..... 259
..... 26
..... 260
..... 261
..... 262
..... 263
..... 264
..... 265
..... 266
..... 267
..... 268
..... 269
..... 27
..... 270
..... 271
..... 272

.....273
.....274
.....275
.....276
.....277
.....278
.....279
.....28
.....280
.....281
.....282
.....283
.....284
.....285
.....286
.....287
.....288
.....289
.....29
.....290
.....291
.....292
.....293
.....294
.....295
.....296
.....297
.....298
.....299
.....3
.....30
.....300
.....301
.....302
.....303
.....304
.....305
.....306
.....307
.....308
.....309
.....31
.....310
.....311
.....312
.....32
.....33
.....34
.....35
.....36
.....37
.....38
.....39
.....4
.....40
.....41
.....42
.....43
.....44
.....45

.....46
.....47
.....48
.....49
.....5
.....50
.....51
.....52
.....53
.....54
.....55
.....56
.....57
.....58
.....59
.....6
.....60
.....61
.....62
.....63
.....64
.....65
.....66
.....67
.....68
.....69
.....7
.....70
.....71
.....72
.....73
.....74
.....75
.....76
.....77
.....78
.....79
.....8
.....80
.....81
.....82
.....83
.....84
.....85
.....86
.....87
.....88
.....89
.....9
.....90
.....91
.....92
.....93
.....94
.....95
.....96
.....97
.....98
.....99
...vars

Evaluate the accuracy performance of the test set

```
In [8]: accuracy_test = model_p1.evaluate(X_test_rs, t_test)

13/13 [=====] - 25s 2s/step - loss: 1.0877 - accuracy: 0.795
2
```

Make test label prediction and report quantitative metrics

```
In [10]: from sklearn.metrics import classification_report

y_test = np.argmax(model_p1.predict(X_test_rs), axis=1)

class_names = ['Roses', 'Magnolias', 'Lilies', 'Sunflowers', 'Orchids',
               'Marigold', 'Hibiscus', 'Firebush', 'Pentas', 'Bougainvillea']

print(classification_report(t_test, y_test, target_names=class_names))
```

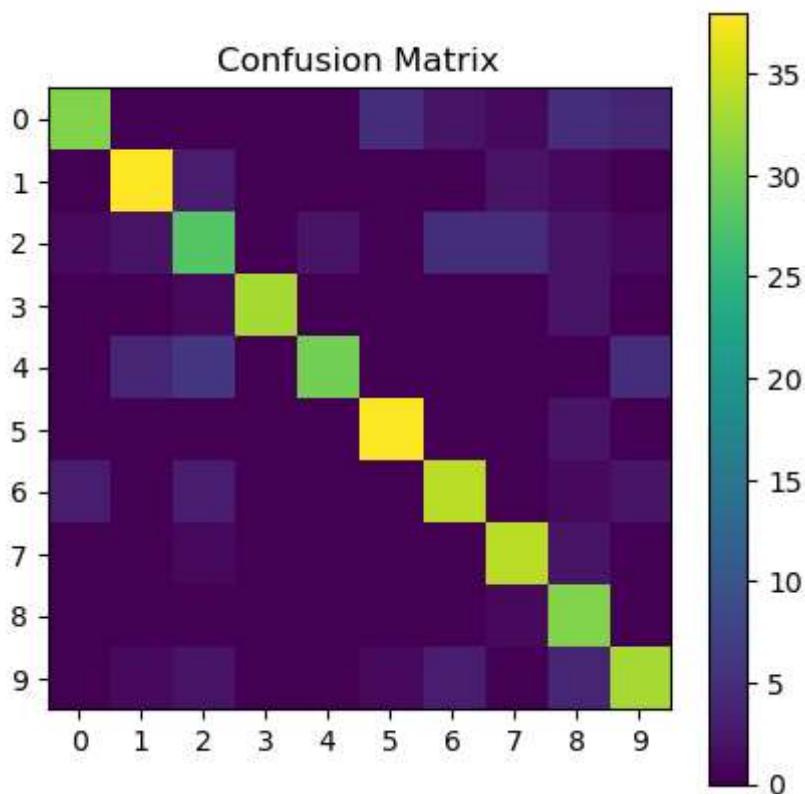
```
13/13 [=====] - 25s 2s/step
      precision    recall  f1-score   support

          Roses       0.89      0.65      0.75      48
        Magnolias     0.84      0.86      0.85      44
         Lilies       0.64      0.61      0.62      46
      Sunflowers     1.00      0.92      0.96      36
        Orchids       0.94      0.67      0.78      45
      Marigold       0.86      0.95      0.90      40
      Hibiscus       0.77      0.79      0.78      43
      Firebush       0.79      0.92      0.85      37
        Pentas       0.62      0.97      0.76      32
Bougainvillea     0.73      0.75      0.74      44

      accuracy           0.80      415
    macro avg       0.81      0.81      0.80      415
  weighted avg     0.81      0.80      0.79      415
```

```
In [12]: from sklearn.metrics import confusion_matrix

plt.figure(figsize=(5,5))
conf_mx = confusion_matrix(t_test, y_test)
plt.imshow(conf_mx)
plt.colorbar()
plt.xticks(range(10))
plt.yticks(range(10));
plt.title('Confusion Matrix');
```



Problem 3 Test Set Evaluation

Load trained model from problem 3

```
In [23]: import joblib  
  
model_p1 = joblib.load('trained_models/Q3_trainedModel_1.pkl');  
model_p2 = joblib.load('trained_models/Q3_trainedModel_2.pkl');  
model_p3 = joblib.load('trained_models/Q3_trainedModel_3.pkl');
```

```
Keras model archive loading:  
File Name                                Modified      Size  
config.json                               2022-12-10 13:51:12    11726  
metadata.json                            2022-12-10 13:51:12      64  
variables.h5                             2022-12-10 13:51:12  64599520  
Keras weights file (<HDF5 file "variables.h5" (mode r)>) loading:  
...layers\conv2d  
.....vars  
.....0  
.....1  
...layers\conv2d_1  
.....vars  
.....0  
.....1  
...layers\conv2d_10  
.....vars  
.....0  
.....1  
...layers\conv2d_11  
.....vars  
.....0  
.....1  
...layers\conv2d_12  
.....vars  
.....0  
.....1  
...layers\conv2d_2  
.....vars  
.....0  
.....1  
...layers\conv2d_3  
.....vars  
.....0  
.....1  
...layers\conv2d_4  
.....vars  
.....0  
.....1  
...layers\conv2d_5  
.....vars  
.....0  
.....1  
...layers\conv2d_6  
.....vars  
.....0  
.....1  
...layers\conv2d_7  
.....vars  
.....0  
.....1  
...layers\conv2d_8  
.....vars  
.....0  
.....1  
...layers\conv2d_9  
.....vars  
.....0  
.....1  
...layers\dense  
.....vars
```

```

.....0
.....1
...layers\flatten
.....vars
...layers\input_layer
.....vars
...layers\max_pooling2d
.....vars
...layers\max_pooling2d_1
.....vars
...layers\max_pooling2d_2
.....vars
...layers\max_pooling2d_3
.....vars
...layers\max_pooling2d_4
.....vars
...metrics\mean
.....vars
.....0
.....1
...metrics\mean_squared_error
.....vars
.....0
.....1
...optimizer
.....vars
.....0
.....1
.....2
.....3
.....4
...vars
Keras model archive loading:
File Name                      Modified      Size
config.json                    2022-12-10 16:16:00    13383
metadata.json                  2022-12-10 16:16:00      64
variables.h5                   2022-12-10 16:16:02  240726064
Keras weights file (<HDF5 file "variables.h5" (mode r)>) loading:
...layers\conv2d
.....vars
.....0
.....1
...layers\conv2d_1
.....vars
.....0
.....1
...layers\conv2d_10
.....vars
.....0
.....1
...layers\conv2d_11
.....vars
.....0
.....1
...layers\conv2d_12
.....vars
.....0
.....1
...layers\conv2d_2
.....vars

```

```
.....0
.....1
...layers\conv2d_3
.....vars
.....0
.....1
...layers\conv2d_4
.....vars
.....0
.....1
...layers\conv2d_5
.....vars
.....0
.....1
...layers\conv2d_6
.....vars
.....0
.....1
...layers\conv2d_7
.....vars
.....0
.....1
...layers\conv2d_8
.....vars
.....0
.....1
...layers\conv2d_9
.....vars
.....0
.....1
...layers\dense
.....vars
.....0
.....1
...layers\dense_1
.....vars
.....0
.....1
...layers\dense_2
.....vars
.....0
.....1
...layers\dense_3
.....vars
.....0
.....1
...layers\flatten
.....vars
...layers\input_layer
.....vars
...layers\max_pooling2d
.....vars
...layers\max_pooling2d_1
.....vars
...layers\max_pooling2d_2
.....vars
...layers\max_pooling2d_3
.....vars
...layers\max_pooling2d_4
.....vars
```

```
...metrics\mean
.....vars
.....0
.....1
...metrics\mean_squared_error
.....vars
.....0
.....1
...optimizer
.....vars
.....0
.....1
.....10
.....11
.....12
.....13
.....14
.....15
.....16
.....2
.....3
.....4
.....5
.....6
.....7
.....8
.....9
...vars
Keras model archive loading:
File Name                      Modified      Size
config.json                    2022-12-10 18:11:00    13012
metadata.json                  2022-12-10 18:11:00       64
variables.h5                   2022-12-10 18:11:00  240726064
Keras weights file (<HDF5 file "variables.h5" (mode r)>) loading:
...layers\conv2d
.....vars
.....0
.....1
...layers\conv2d_1
.....vars
.....0
.....1
...layers\conv2d_10
.....vars
.....0
.....1
...layers\conv2d_11
.....vars
.....0
.....1
...layers\conv2d_12
.....vars
.....0
.....1
...layers\conv2d_2
.....vars
.....0
.....1
...layers\conv2d_3
.....vars
```

```
.....0
.....1
...layers\conv2d_4
.....vars
.....0
.....1
...layers\conv2d_5
.....vars
.....0
.....1
...layers\conv2d_6
.....vars
.....0
.....1
...layers\conv2d_7
.....vars
.....0
.....1
...layers\conv2d_8
.....vars
.....0
.....1
...layers\conv2d_9
.....vars
.....0
.....1
...layers\dense
.....vars
.....0
.....1
...layers\dense_1
.....vars
.....0
.....1
...layers\dense_2
.....vars
.....0
.....1
...layers\dense_3
.....vars
.....0
.....1
...layers\flatten
.....vars
...layers\input_layer
.....vars
...layers\max_pooling2d
.....vars
...layers\max_pooling2d_1
.....vars
...layers\max_pooling2d_2
.....vars
...layers\max_pooling2d_3
.....vars
...layers\max_pooling2d_4
.....vars
...metrics\mean
.....vars
.....0
.....1
```

```
...metrics\mean_metric_wrapper
.....vars
.....0
.....1
...optimizer
.....vars
.....0
.....1
.....10
.....11
.....12
.....13
.....14
.....15
.....16
.....2
.....3
.....4
.....5
.....6
.....7
.....8
.....9
...vars
```

In [7]:

```
bbox = pd.read_csv('car_detection_dataset/testing_img_names.csv')
# Load test set and labels
N = len(bbox) # no. of training samples

# Create a numpy array with all images
for i in range(N):
    filename='car_detection_dataset/testing_images/'+bbox['image'][i]
    image = np.array(Image.open(filename))
    image_col = image.ravel()[:,np.newaxis]

    if i==0:
        X_test = image_col
    else:
        X_test = np.hstack((X_test, image_col))

# Test feature matrices
X_test = X_test.T

# Test Labels
t_test = bbox.drop('image', axis=1).round().to_numpy().astype(int)

X_test.shape, t_test.shape
```

Out[7]:

```
((175, 770640), (175, 0))
```

In [9]:

```
# reshape test set to tensors
X_test_rs = tf.constant(X_test.reshape((X_test.shape[0], 380, 676, 3)),
                        dtype=tf.float32)
```

Make test label prediction and report quantitative metrics

In [47]:

```
y_test_1 = model_p1.predict(X_test_rs).astype(int)
```

```
6/6 [=====] - 154s 25s/step
```

```
In [48]: y_test_2 = model_p2.predict(X_test_rs).astype(int)
```

```
6/6 [=====] - 155s 25s/step
```

```
In [49]: y_test_3 = model_p3.predict(X_test_rs).astype(int)
```

```
6/6 [=====] - 150s 24s/step
```

model 1 result visualization

```
In [50]: # Example of object visualization using opencv rectangle function
```

```
idx=N-1
```

```
x= image
```

```
plt.imshow(x)
cv2.rectangle(x, (y_test_1[idx][0], y_test_1[idx][1]),
              (y_test_1[idx][2], y_test_1[idx][3]),
              (255, 0, 0), 2);
```



model 3 result visualization

```
In [51]: # Example of object visualization using opencv rectangle function
```

```
idx=N-1
```

```
x= image
```

```
plt.imshow(x)
cv2.rectangle(x, (y_test_2[idx][0], y_test_2[idx][1]),
              (y_test_2[idx][2], y_test_2[idx][3]),
              (255, 0, 0), 2);
```



model 3 result visualization

```
In [52]: # Example of object visualization using opencv rectangle function
idx=N-1
x= image

plt.imshow(x)
cv2.rectangle(x, (y_test_3[idx][0], y_test_3[idx][1]),
              (y_test_3[idx][2], y_test_3[idx][3]),
              (255, 0, 0), 2);
```



As we can see, the results are not very accurate, which is expected from the large MSE score returned in the training and validation sets.

```
In [ ]:
```