Classifying Flowers using Transfer Learning in Keras

1- Download a small flower dataset (http://download.tensorflow.org/example_images/flower_photos.tgz (http://download.tensorflow.org/example_images/flower_photos.tgz)). This dataset has 5 classes (Daisy, Dandelion, Rese, Sunflower, and Tulip). Images for each class are stored in its own folder.

2- The images have different dimensions. Resize all of them to 150x150.

3- Split images to 75-25% for training and test. Make sure you have the same distribution of flower types between train and test datasets.

4- Use a VGG16 model (pre-trained on ImageNet)

5- Remove the top layers (fully connected layers)

6- Add your own fully connected layers (one with 256 nodes using 'relu' activation and output layer with 5 nodes and 'softmax' activation)

7- First, freeze all layers of VGG16, train (fine-tune) and evaluate the model. You need to pick the right hyper-parameters for your training (try with different ones)

8- Second, unfreeze the last block of VGG16 (block5), re-train and evaluate the model

9- Unfreeze all the layers and try again.

10- Compare the accuracy you got in both cases . Which one is better and why?

Setup

In [1]:

```
# if True, will download the pictures
# set to True only the first time you are running this notebook
download_pictures = True
```

In [2]:

```
from keras import optimizers
from keras.callbacks import EarlyStopping

image_w, image_h = 150, 150
batch_size = 20
epochs = 5
loss = "sparse_categorical_crossentropy"
metrics = ["accuracy"]
optimizer = optimizers.SGD(lr=0.0001, momentum=0.9)
es = EarlyStopping(monitor='accuracy', mode='min', verbose=1)
weights = "imagenet"
```

```
Using TensorFlow backend.
```

In [3]:

```
from IPython.display import Image
import warnings
warnings.filterwarnings("ignore")
warnings.simplefilter("ignore")
from setups import *
from plotting import *
from keras import applications
from keras.models import Sequential, Model
from keras.layers import Dropout, Flatten, Dense, GlobalAveragePooling2D
```

In [4]:

```
# Trainable layers
def printTrainableLayers(model):
    for i, layer in enumerate(model.layers):
        print(i, layer.name, layer.trainable)
```

In [5]:

```
def printAccuracy(score):
    print('Test loss:', score[0])
    print('Test accuracy:', score[1])
```

Data Preparation

In [6]:

```
import urllib.request
import tarfile

local_filename = 'flower_photos.tgz'

# download the pictures depending on the flag
if download_pictures:
    local_filename, headers = urllib.request.urlretrieve('http://download.tensorf
                                                    filename=local_filename)
    print(headers)
    tar = tarfile.open(local_filename, "r:gz")
    tar.extractall(path=".")
    tar.close()
```

```
X-GUploader-UploadID: AEnB2UpxwB20XxjANoyEk4wi0jwgAfvjXcMtf2SvNSyjhA24wbQhMesDL
8gFUApwTVU1jNM1XNmbZCQb3RsCZPdxU4mPQLH6Qw
Expires: Sun, 16 Feb 2020 17:36:50 GMT
Date: Sun, 16 Feb 2020 16:36:50 GMT
Cache-Control: public, max-age=3600
Last-Modified: Wed, 10 Feb 2016 20:55:04 GMT
ETag: "6f87fb78e9cc9ab41eff2015b380011d"
x-goog-generation: 1455137704468000
x-goog-metageneration: 2
x-goog-stored-content-encoding: identity
x-goog-stored-content-length: 228813984
Content-Type: application/x-compressed-tar
x-goog-hash: crc32c=vcj3DQ==
x-goog-hash: md5=b4f7eOnMmrQe/yAVs4ABHQ==
x-goog-storage-class: STANDARD
Accept-Ranges: bytes
Content-Length: 228813984
Server: UploadServer
Connection: close
```

In [7]:

```python
from tensorflow.keras.preprocessing.image import ImageDataGenerator

train_dir = "flower_photos"

# All images will be rescaled by 1./255
train_datagen = ImageDataGenerator(rescale=1./255, validation_split=0.25)

train_generator = train_datagen.flow_from_directory(
        # This is the target directory
        train_dir,
        # All images will be resized to 150x150
        target_size=(image_w, image_h),
        batch_size=batch_size,
        # Since we use binary_crossentropy loss, we need binary labels
        class_mode='binary',
        subset='training')

test_generator = train_datagen.flow_from_directory(
        # This is the target directory
        train_dir,
        # All images will be resized to 150x150
        target_size=(image_w, image_h),
        batch_size=batch_size,
        # Since we use binary_crossentropy loss, we need binary labels
        class_mode='binary',
        subset='validation')
```

```
Found 2755 images belonging to 5 classes.
Found 915 images belonging to 5 classes.
```

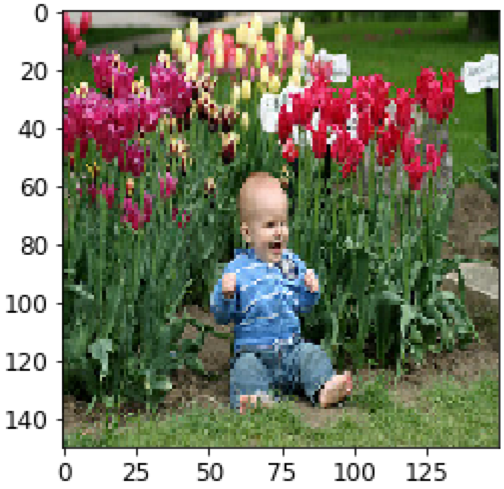
In [8]:

```python
from tensorflow.keras.preprocessing import image

def printImage(generator):
    for data_batch, labels_batch in train_generator:
        plt.figure(0)
        imgplot = plt.imshow(image.array_to_img(data_batch[0]))
        print('Data batch shape:', data_batch.shape)
        print('Labels batch shape:', labels_batch.shape)
        break
```

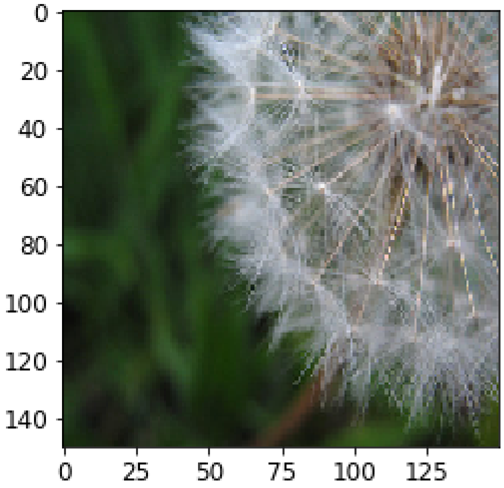
In [9]:
```
print('Training data')
printImage(train_generator)
```

```
Training data
Data batch shape: (20, 150, 150, 3)
Labels batch shape: (20,)
```



```
In [10]: print('Testing data')
         printImage(test_generator)
```

```
Testing data
Data batch shape: (20, 150, 150, 3)
Labels batch shape: (20,)
```



Model1

Hyperparameters Set 1

applications.VGG16.pooling=None

optimizers.SGD(lr=0.0001, momentum=0.9)

In [11]:

```
# VGG16 pre-trained model without fully connected layers and with different input
model1 = applications.VGG16(weights = weights, include_top=False, input_shape = (
# Freezing all layers
for layer in model1.layers:
    layer.trainable = False
printTrainableLayers(model1)
model1.summary()
```

```
0 input_1 False
1 block1_conv1 False
2 block1_conv2 False
3 block1_pool False
4 block2_conv1 False
5 block2_conv2 False
6 block2_pool False
7 block3_conv1 False
8 block3_conv2 False
9 block3_conv3 False
10 block3_pool False
11 block4_conv1 False
12 block4_conv2 False
13 block4_conv3 False
14 block4_pool False
15 block5_conv1 False
16 block5_conv2 False
17 block5_conv3 False
18 block5_pool False
Model: "vgg16"
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
input_1 (InputLayer)         (None, 150, 150, 3)       0         
_________________________________________________________________
block1_conv1 (Conv2D)        (None, 150, 150, 64)      1792      
_________________________________________________________________
block1_conv2 (Conv2D)        (None, 150, 150, 64)      36928     
_________________________________________________________________
block1_pool (MaxPooling2D)   (None, 75, 75, 64)        0         
_________________________________________________________________
block2_conv1 (Conv2D)        (None, 75, 75, 128)       73856     
_________________________________________________________________
block2_conv2 (Conv2D)        (None, 75, 75, 128)       147584    
_________________________________________________________________
block2_pool (MaxPooling2D)   (None, 37, 37, 128)       0         
_________________________________________________________________
block3_conv1 (Conv2D)        (None, 37, 37, 256)       295168    
_________________________________________________________________
block3_conv2 (Conv2D)        (None, 37, 37, 256)       590080    
_________________________________________________________________
block3_conv3 (Conv2D)        (None, 37, 37, 256)       590080    
_________________________________________________________________
block3_pool (MaxPooling2D)   (None, 18, 18, 256)       0         
_________________________________________________________________
block4_conv1 (Conv2D)        (None, 18, 18, 512)       1180160   
_________________________________________________________________
block4_conv2 (Conv2D)        (None, 18, 18, 512)       2359808   
```

```
_________________________________________________________________
block4_conv3 (Conv2D)        (None, 18, 18, 512)       2359808   
_________________________________________________________________
block4_pool (MaxPooling2D)   (None, 9, 9, 512)         0         
_________________________________________________________________
block5_conv1 (Conv2D)        (None, 9, 9, 512)         2359808   
_________________________________________________________________
block5_conv2 (Conv2D)        (None, 9, 9, 512)         2359808   
_________________________________________________________________
block5_conv3 (Conv2D)        (None, 9, 9, 512)         2359808   
_________________________________________________________________
block5_pool (MaxPooling2D)   (None, 4, 4, 512)         0         
=================================================================
Total params: 14,714,688
Trainable params: 0
Non-trainable params: 14,714,688
_________________________________________________________________
```

In [12]:

```python
# Adding custom layers to create a new model
new_model1 = Sequential([
    model1,
    Flatten(name='flatten'),
    Dense(256, activation='relu', name='new_fc1'),
    Dense(5, activation='softmax', name='new_predictions')
])
new_model1.summary()
```

```
Model: "sequential_1"
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
vgg16 (Model)                (None, 4, 4, 512)         14714688  
_________________________________________________________________
flatten (Flatten)            (None, 8192)              0         
_________________________________________________________________
new_fc1 (Dense)              (None, 256)               2097408   
_________________________________________________________________
new_predictions (Dense)      (None, 5)                 1285      
=================================================================
Total params: 16,813,381
Trainable params: 2,098,693
Non-trainable params: 14,714,688
_________________________________________________________________
```

In [13]:
```
# Compiling the model
new_model1.compile(loss=loss, optimizer=optimizer, metrics=metrics)

# training
new_model1.fit_generator(train_generator,epochs=epochs,verbose=1, callbacks=[es]
score1 = new_model1.evaluate(test_generator, verbose=1)
printAccuracy(score1)
```

```
Epoch 1/5
138/138 [==============================] - 355s 3s/step - loss: 1.4408 - accura
cy: 0.3996
Epoch 2/5
138/138 [==============================] - 304s 2s/step - loss: 1.1175 - accura
cy: 0.6149
Epoch 00002: early stopping
46/46 [==============================] - 77s 2s/step
Test loss: 1.07350754737854
Test accuracy: 0.568306028842926
```

Hyperparameters Set 2

applications.VGG16.pooling='avg'

optimizers.SGD(lr=0.0001, momentum=0.9)

In [14]:

```
# VGG16 pre-trained model without fully connected layers and with different input
model1_hp2 = applications.VGG16(weights = weights, include_top=False, input_shape
# Freezing all layers
for layer in model1_hp2.layers:
    layer.trainable = False
printTrainableLayers(model1_hp2)
model1_hp2.summary()
```

```
0 input_2 False
1 block1_conv1 False
2 block1_conv2 False
3 block1_pool False
4 block2_conv1 False
5 block2_conv2 False
6 block2_pool False
7 block3_conv1 False
8 block3_conv2 False
9 block3_conv3 False
10 block3_pool False
11 block4_conv1 False
12 block4_conv2 False
13 block4_conv3 False
14 block4_pool False
15 block5_conv1 False
16 block5_conv2 False
17 block5_conv3 False
18 block5_pool False
19 global_average_pooling2d_1 False
Model: "vgg16"
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
input_2 (InputLayer)         (None, 150, 150, 3)       0         
_________________________________________________________________
block1_conv1 (Conv2D)        (None, 150, 150, 64)      1792      
_________________________________________________________________
block1_conv2 (Conv2D)        (None, 150, 150, 64)      36928     
_________________________________________________________________
block1_pool (MaxPooling2D)   (None, 75, 75, 64)        0         
_________________________________________________________________
block2_conv1 (Conv2D)        (None, 75, 75, 128)       73856     
_________________________________________________________________
block2_conv2 (Conv2D)        (None, 75, 75, 128)       147584    
_________________________________________________________________
block2_pool (MaxPooling2D)   (None, 37, 37, 128)       0         
_________________________________________________________________
block3_conv1 (Conv2D)        (None, 37, 37, 256)       295168    
_________________________________________________________________
block3_conv2 (Conv2D)        (None, 37, 37, 256)       590080    
_________________________________________________________________
block3_conv3 (Conv2D)        (None, 37, 37, 256)       590080    
_________________________________________________________________
block3_pool (MaxPooling2D)   (None, 18, 18, 256)       0         
_________________________________________________________________
block4_conv1 (Conv2D)        (None, 18, 18, 512)       1180160   
_________________________________________________________________
```

```
block4_conv2 (Conv2D)        (None, 18, 18, 512)       2359808   
_________________________________________________________________
block4_conv3 (Conv2D)        (None, 18, 18, 512)       2359808   
_________________________________________________________________
block4_pool (MaxPooling2D)   (None, 9, 9, 512)         0         
_________________________________________________________________
block5_conv1 (Conv2D)        (None, 9, 9, 512)         2359808   
_________________________________________________________________
block5_conv2 (Conv2D)        (None, 9, 9, 512)         2359808   
_________________________________________________________________
block5_conv3 (Conv2D)        (None, 9, 9, 512)         2359808   
_________________________________________________________________
block5_pool (MaxPooling2D)   (None, 4, 4, 512)         0         
_________________________________________________________________
global_average_pooling2d_1 ( (None, 512)               0         
=================================================================
Total params: 14,714,688
Trainable params: 0
Non-trainable params: 14,714,688
_________________________________________________________________
```

In [15]:

```
# Adding custom layers to create a new model
new_model1_hp2 = Sequential([
    model1_hp2,
    #Flatten(name='flatten'),
    Dense(256, activation='relu', name='new_fc1'),
    Dense(5, activation='softmax', name='new_predictions')
])
new_model1_hp2.summary()
```

```
Model: "sequential_2"
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
vgg16 (Model)                (None, 512)               14714688  
_________________________________________________________________
new_fc1 (Dense)              (None, 256)               131328    
_________________________________________________________________
new_predictions (Dense)      (None, 5)                 1285      
=================================================================
Total params: 14,847,301
Trainable params: 132,613
Non-trainable params: 14,714,688
_________________________________________________________________
```

In [16]:

```
# Compiling the model
new_model1_hp2.compile(loss=loss, optimizer=optimizer, metrics=metrics)

# training
new_model1_hp2.fit_generator(train_generator,epochs=epochs,verbose=1, callbacks=
score1_hp2 = new_model1.evaluate(test_generator, verbose=1)
printAccuracy(score1_hp2)
```

```
Epoch 1/5
138/138 [==============================] - 245s 2s/step - loss: 1.6216 - accura
cy: 0.2613
Epoch 2/5
138/138 [==============================] - 251s 2s/step - loss: 1.5519 - accura
cy: 0.3557
Epoch 00002: early stopping
46/46 [==============================] - 81s 2s/step
Test loss: 0.9861659407615662
Test accuracy: 0.568306028842926
```

Type *Markdown* and LaTeX: α^2

Hyperparameters Set 3

applications.VGG16.pooling='max'

optimizers.SGD(lr=0.0001, momentum=0.9)

In [17]:
```
# VGG16 pre-trained model without fully connected layers and with different input
model1_hp3 = applications.VGG16(weights = weights, include_top=False, input_shape
# Freezing all layers
for layer in model1_hp3.layers:
    layer.trainable = False
printTrainableLayers(model1_hp3)
model1_hp3.summary()
```

```
0 input_3 False
1 block1_conv1 False
2 block1_conv2 False
3 block1_pool False
4 block2_conv1 False
5 block2_conv2 False
6 block2_pool False
7 block3_conv1 False
8 block3_conv2 False
9 block3_conv3 False
10 block3_pool False
11 block4_conv1 False
12 block4_conv2 False
13 block4_conv3 False
14 block4_pool False
15 block5_conv1 False
16 block5_conv2 False
17 block5_conv3 False
18 block5_pool False
19 global_max_pooling2d_1 False
Model: "vgg16"
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
input_3 (InputLayer)         (None, 150, 150, 3)       0         
_________________________________________________________________
block1_conv1 (Conv2D)        (None, 150, 150, 64)      1792      
_________________________________________________________________
block1_conv2 (Conv2D)        (None, 150, 150, 64)      36928     
_________________________________________________________________
block1_pool (MaxPooling2D)   (None, 75, 75, 64)        0         
_________________________________________________________________
block2_conv1 (Conv2D)        (None, 75, 75, 128)       73856     
_________________________________________________________________
block2_conv2 (Conv2D)        (None, 75, 75, 128)       147584    
_________________________________________________________________
block2_pool (MaxPooling2D)   (None, 37, 37, 128)       0         
_________________________________________________________________
block3_conv1 (Conv2D)        (None, 37, 37, 256)       295168    
_________________________________________________________________
block3_conv2 (Conv2D)        (None, 37, 37, 256)       590080    
_________________________________________________________________
block3_conv3 (Conv2D)        (None, 37, 37, 256)       590080    
_________________________________________________________________
block3_pool (MaxPooling2D)   (None, 18, 18, 256)       0         
_________________________________________________________________
block4_conv1 (Conv2D)        (None, 18, 18, 512)       1180160   
_________________________________________________________________
```

```
block4_conv2 (Conv2D)        (None, 18, 18, 512)       2359808
_________________________________________________________________
block4_conv3 (Conv2D)        (None, 18, 18, 512)       2359808
_________________________________________________________________
block4_pool (MaxPooling2D)   (None, 9, 9, 512)         0
_________________________________________________________________
block5_conv1 (Conv2D)        (None, 9, 9, 512)         2359808
_________________________________________________________________
block5_conv2 (Conv2D)        (None, 9, 9, 512)         2359808
_________________________________________________________________
block5_conv3 (Conv2D)        (None, 9, 9, 512)         2359808
_________________________________________________________________
block5_pool (MaxPooling2D)   (None, 4, 4, 512)         0
_________________________________________________________________
global_max_pooling2d_1 (Glob (None, 512)               0
=================================================================
Total params: 14,714,688
Trainable params: 0
Non-trainable params: 14,714,688
_________________________________________________________________
```

In [18]:

```
# Adding custom layers to create a new model
new_model1_hp3 = Sequential([
    model1_hp3,
    #Flatten(name='flatten'),
    Dense(256, activation='relu', name='new_fc1'),
    Dense(5, activation='softmax', name='new_predictions')
])
new_model1_hp3.summary()
```

```
Model: "sequential_3"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
vgg16 (Model)                (None, 512)               14714688
_________________________________________________________________
new_fc1 (Dense)              (None, 256)               131328
_________________________________________________________________
new_predictions (Dense)      (None, 5)                 1285
=================================================================
Total params: 14,847,301
Trainable params: 132,613
Non-trainable params: 14,714,688
_________________________________________________________________
```

In [19]:
```
# Compiling the model
new_model1_hp3.compile(loss=loss, optimizer=optimizer, metrics=metrics)

# training
new_model1_hp3.fit_generator(train_generator,epochs=epochs,verbose=1, callbacks=
score1_hp3 = new_model1.evaluate(test_generator, verbose=1)
printAccuracy(score1_hp3)
```

```
Epoch 1/5
138/138 [==============================] - 256s 2s/step - loss: 1.6767 - accura
cy: 0.2497
Epoch 2/5
138/138 [==============================] - 263s 2s/step - loss: 1.4575 - accura
cy: 0.4105
Epoch 00002: early stopping
46/46 [==============================] - 83s 2s/step
Test loss: 0.8395287990570068
Test accuracy: 0.568306028842926
```

Hyperparameters Set 4

applications.VGG16.pooling=None

optimizers.SGD(lr=0.01, momentum=0.9)

In [20]:

```
# VGG16 pre-trained model without fully connected layers and with different input
model1_hp4 = applications.VGG16(weights = weights, include_top=False, input_shape
# Freezing all layers
for layer in model1_hp4.layers:
    layer.trainable = False
printTrainableLayers(model1_hp4)
model1_hp4.summary()
```

```
0 input_4 False
1 block1_conv1 False
2 block1_conv2 False
3 block1_pool False
4 block2_conv1 False
5 block2_conv2 False
6 block2_pool False
7 block3_conv1 False
8 block3_conv2 False
9 block3_conv3 False
10 block3_pool False
11 block4_conv1 False
12 block4_conv2 False
13 block4_conv3 False
14 block4_pool False
15 block5_conv1 False
16 block5_conv2 False
17 block5_conv3 False
18 block5_pool False
Model: "vgg16"
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
input_4 (InputLayer)         (None, 150, 150, 3)       0         
_________________________________________________________________
block1_conv1 (Conv2D)        (None, 150, 150, 64)      1792      
_________________________________________________________________
block1_conv2 (Conv2D)        (None, 150, 150, 64)      36928     
_________________________________________________________________
block1_pool (MaxPooling2D)   (None, 75, 75, 64)        0         
_________________________________________________________________
block2_conv1 (Conv2D)        (None, 75, 75, 128)       73856     
_________________________________________________________________
block2_conv2 (Conv2D)        (None, 75, 75, 128)       147584    
_________________________________________________________________
block2_pool (MaxPooling2D)   (None, 37, 37, 128)       0         
_________________________________________________________________
block3_conv1 (Conv2D)        (None, 37, 37, 256)       295168    
_________________________________________________________________
block3_conv2 (Conv2D)        (None, 37, 37, 256)       590080    
_________________________________________________________________
block3_conv3 (Conv2D)        (None, 37, 37, 256)       590080    
_________________________________________________________________
block3_pool (MaxPooling2D)   (None, 18, 18, 256)       0         
_________________________________________________________________
block4_conv1 (Conv2D)        (None, 18, 18, 512)       1180160   
_________________________________________________________________
block4_conv2 (Conv2D)        (None, 18, 18, 512)       2359808   
```

```
_________________________________________________________________
block4_conv3 (Conv2D)        (None, 18, 18, 512)       2359808   
_________________________________________________________________
block4_pool (MaxPooling2D)   (None, 9, 9, 512)         0         
_________________________________________________________________
block5_conv1 (Conv2D)        (None, 9, 9, 512)         2359808   
_________________________________________________________________
block5_conv2 (Conv2D)        (None, 9, 9, 512)         2359808   
_________________________________________________________________
block5_conv3 (Conv2D)        (None, 9, 9, 512)         2359808   
_________________________________________________________________
block5_pool (MaxPooling2D)   (None, 4, 4, 512)         0         
=================================================================
Total params: 14,714,688
Trainable params: 0
Non-trainable params: 14,714,688
_________________________________________________________________
```

In [21]:

```python
# Adding custom layers to create a new model
new_model1_hp4 = Sequential([
    model1_hp4,
    Flatten(name='flatten'),
    Dense(256, activation='relu', name='new_fc1'),
    Dense(5, activation='softmax', name='new_predictions')
])
new_model1_hp4.summary()
```

```
Model: "sequential_4"
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
vgg16 (Model)                (None, 4, 4, 512)         14714688  
_________________________________________________________________
flatten (Flatten)            (None, 8192)              0         
_________________________________________________________________
new_fc1 (Dense)              (None, 256)               2097408   
_________________________________________________________________
new_predictions (Dense)      (None, 5)                 1285      
=================================================================
Total params: 16,813,381
Trainable params: 2,098,693
Non-trainable params: 14,714,688
_________________________________________________________________
```

In [22]:
```
# Compiling the model
new_model1_hp4.compile(loss=loss, optimizer=optimizers.SGD(lr=0.01, momentum=0.9

# training
new_model1_hp4.fit_generator(train_generator,epochs=epochs,verbose=1, callbacks=
score1_hp4 = new_model1.evaluate(test_generator, verbose=1)
printAccuracy(score1_hp4)
```

```
Epoch 1/5
138/138 [==============================] - 257s 2s/step - loss: 1.3384 - accura
cy: 0.4835
Epoch 2/5
138/138 [==============================] - 267s 2s/step - loss: 1.1755 - accura
cy: 0.5143
Epoch 00002: early stopping
46/46 [==============================] - 86s 2s/step
Test loss: 1.5730615854263306
Test accuracy: 0.568306028842926
```

Hyperparameters Set 5

applications.VGG16.pooling=None

optimizers.SGD(lr=0.0001, momentum=0.45)

In [23]:

```
# VGG16 pre-trained model without fully connected layers and with different input
model1_hp5 = applications.VGG16(weights = weights, include_top=False, input_shape
# Freezing all layers
for layer in model1_hp5.layers:
    layer.trainable = False
printTrainableLayers(model1_hp5)
model1_hp5.summary()
```

```
0 input_5 False
1 block1_conv1 False
2 block1_conv2 False
3 block1_pool False
4 block2_conv1 False
5 block2_conv2 False
6 block2_pool False
7 block3_conv1 False
8 block3_conv2 False
9 block3_conv3 False
10 block3_pool False
11 block4_conv1 False
12 block4_conv2 False
13 block4_conv3 False
14 block4_pool False
15 block5_conv1 False
16 block5_conv2 False
17 block5_conv3 False
18 block5_pool False
Model: "vgg16"
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
input_5 (InputLayer)         (None, 150, 150, 3)       0         
_________________________________________________________________
block1_conv1 (Conv2D)        (None, 150, 150, 64)      1792      
_________________________________________________________________
block1_conv2 (Conv2D)        (None, 150, 150, 64)      36928     
_________________________________________________________________
block1_pool (MaxPooling2D)   (None, 75, 75, 64)        0         
_________________________________________________________________
block2_conv1 (Conv2D)        (None, 75, 75, 128)       73856     
_________________________________________________________________
block2_conv2 (Conv2D)        (None, 75, 75, 128)       147584    
_________________________________________________________________
block2_pool (MaxPooling2D)   (None, 37, 37, 128)       0         
_________________________________________________________________
block3_conv1 (Conv2D)        (None, 37, 37, 256)       295168    
_________________________________________________________________
block3_conv2 (Conv2D)        (None, 37, 37, 256)       590080    
_________________________________________________________________
block3_conv3 (Conv2D)        (None, 37, 37, 256)       590080    
_________________________________________________________________
block3_pool (MaxPooling2D)   (None, 18, 18, 256)       0         
_________________________________________________________________
block4_conv1 (Conv2D)        (None, 18, 18, 512)       1180160   
_________________________________________________________________
block4_conv2 (Conv2D)        (None, 18, 18, 512)       2359808   
```

```
_________________________________________________________________
block4_conv3 (Conv2D)        (None, 18, 18, 512)       2359808   
_________________________________________________________________
block4_pool (MaxPooling2D)   (None, 9, 9, 512)         0         
_________________________________________________________________
block5_conv1 (Conv2D)        (None, 9, 9, 512)         2359808   
_________________________________________________________________
block5_conv2 (Conv2D)        (None, 9, 9, 512)         2359808   
_________________________________________________________________
block5_conv3 (Conv2D)        (None, 9, 9, 512)         2359808   
_________________________________________________________________
block5_pool (MaxPooling2D)   (None, 4, 4, 512)         0         
=================================================================
Total params: 14,714,688
Trainable params: 0
Non-trainable params: 14,714,688
_________________________________________________________________
```

In [24]:

```
# Adding custom layers to create a new model
new_model1_hp5 = Sequential([
    model1_hp5,
    Flatten(name='flatten'),
    Dense(256, activation='relu', name='new_fc1'),
    Dense(5, activation='softmax', name='new_predictions')
])
new_model1_hp5.summary()
```

```
Model: "sequential_5"
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
vgg16 (Model)                (None, 4, 4, 512)         14714688  
_________________________________________________________________
flatten (Flatten)            (None, 8192)              0         
_________________________________________________________________
new_fc1 (Dense)              (None, 256)               2097408   
_________________________________________________________________
new_predictions (Dense)      (None, 5)                 1285      
=================================================================
Total params: 16,813,381
Trainable params: 2,098,693
Non-trainable params: 14,714,688
_________________________________________________________________
```

In [25]:
```
# Compiling the model
new_model1_hp5.compile(loss=loss, optimizer=optimizers.SGD(lr=0.0001, momentum=0.

# training
new_model1_hp5.fit_generator(train_generator,epochs=epochs,verbose=1, callbacks=[
score1_hp5 = new_model1.evaluate(test_generator, verbose=1)
printAccuracy(score1_hp5)
```

```
Epoch 1/5
138/138 [==============================] - 257s 2s/step - loss: 1.5677 - accura
cy: 0.3136
Epoch 2/5
138/138 [==============================] - 263s 2s/step - loss: 1.4456 - accura
cy: 0.4345
Epoch 00002: early stopping
46/46 [==============================] - 84s 2s/step
Test loss: 0.975836455821991
Test accuracy: 0.568306028842926
```

Model2

In [26]:

```
# VGG16 pre-trained model without fully connected layers and with different input
model2 = applications.VGG16(weights = weights, include_top=False, input_shape = (
# Freezing the layers until block5
for layer in model2.layers[:15]:
    layer.trainable = False
printTrainableLayers(model2)
model2.summary()
```

```
0 input_6 False
1 block1_conv1 False
2 block1_conv2 False
3 block1_pool False
4 block2_conv1 False
5 block2_conv2 False
6 block2_pool False
7 block3_conv1 False
8 block3_conv2 False
9 block3_conv3 False
10 block3_pool False
11 block4_conv1 False
12 block4_conv2 False
13 block4_conv3 False
14 block4_pool False
15 block5_conv1 True
16 block5_conv2 True
17 block5_conv3 True
18 block5_pool True
Model: "vgg16"
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
input_6 (InputLayer)         (None, 150, 150, 3)       0         
_________________________________________________________________
block1_conv1 (Conv2D)        (None, 150, 150, 64)      1792      
_________________________________________________________________
block1_conv2 (Conv2D)        (None, 150, 150, 64)      36928     
_________________________________________________________________
block1_pool (MaxPooling2D)   (None, 75, 75, 64)        0         
_________________________________________________________________
block2_conv1 (Conv2D)        (None, 75, 75, 128)       73856     
_________________________________________________________________
block2_conv2 (Conv2D)        (None, 75, 75, 128)       147584    
_________________________________________________________________
block2_pool (MaxPooling2D)   (None, 37, 37, 128)       0         
_________________________________________________________________
block3_conv1 (Conv2D)        (None, 37, 37, 256)       295168    
_________________________________________________________________
block3_conv2 (Conv2D)        (None, 37, 37, 256)       590080    
_________________________________________________________________
block3_conv3 (Conv2D)        (None, 37, 37, 256)       590080    
_________________________________________________________________
block3_pool (MaxPooling2D)   (None, 18, 18, 256)       0         
_________________________________________________________________
block4_conv1 (Conv2D)        (None, 18, 18, 512)       1180160   
_________________________________________________________________
block4_conv2 (Conv2D)        (None, 18, 18, 512)       2359808   
```

```
_________________________________________________________________
block4_conv3 (Conv2D)        (None, 18, 18, 512)       2359808   
_________________________________________________________________
block4_pool (MaxPooling2D)   (None, 9, 9, 512)         0         
_________________________________________________________________
block5_conv1 (Conv2D)        (None, 9, 9, 512)         2359808   
_________________________________________________________________
block5_conv2 (Conv2D)        (None, 9, 9, 512)         2359808   
_________________________________________________________________
block5_conv3 (Conv2D)        (None, 9, 9, 512)         2359808   
_________________________________________________________________
block5_pool (MaxPooling2D)   (None, 4, 4, 512)         0         
=================================================================
Total params: 14,714,688
Trainable params: 7,079,424
Non-trainable params: 7,635,264
_________________________________________________________________
```

In [27]:

```
# Adding custom layers to create a new model
new_model2 = Sequential([
    model2,
    Flatten(name='flatten'),
    Dense(256, activation='relu', name='new_fc1'),
    Dense(5, activation='softmax', name='new_predictions')
])
new_model2.summary()
```

```
Model: "sequential_6"
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
vgg16 (Model)                (None, 4, 4, 512)         14714688  
_________________________________________________________________
flatten (Flatten)            (None, 8192)              0         
_________________________________________________________________
new_fc1 (Dense)              (None, 256)               2097408   
_________________________________________________________________
new_predictions (Dense)      (None, 5)                 1285      
=================================================================
Total params: 16,813,381
Trainable params: 9,178,117
Non-trainable params: 7,635,264
_________________________________________________________________
```

In [28]:

```
# Compiling the model
new_model2.compile(loss=loss, optimizer=optimizer, metrics=metrics)

# training
new_model2.fit_generator(train_generator,epochs=epochs,verbose=1, callbacks=[es])
score2 = new_model2.evaluate(test_generator, verbose=1)
printAccuracy(score2)
```

```
Epoch 1/5
138/138 [==============================] - 319s 2s/step - loss: 1.2891 - accura
cy: 0.4955
Epoch 2/5
138/138 [==============================] - 334s 2s/step - loss: 0.7258 - accura
cy: 0.7514
Epoch 00002: early stopping
46/46 [==============================] - 90s 2s/step
Test loss: 0.7680565118789673
Test accuracy: 0.7289617657661438
```

In [ ]:

Model3

In [29]:

```
# VGG16 pre-trained model without fully connected layers and with different input
model3 = applications.VGG16(weights = weights, include_top=False, input_shape = (
# all layers will be trainable
printTrainableLayers(model3)
model3.summary()
```

```
0 input_7 False
1 block1_conv1 True
2 block1_conv2 True
3 block1_pool True
4 block2_conv1 True
5 block2_conv2 True
6 block2_pool True
7 block3_conv1 True
8 block3_conv2 True
9 block3_conv3 True
10 block3_pool True
11 block4_conv1 True
12 block4_conv2 True
13 block4_conv3 True
14 block4_pool True
15 block5_conv1 True
16 block5_conv2 True
17 block5_conv3 True
18 block5_pool True
Model: "vgg16"
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
input_7 (InputLayer)         (None, 150, 150, 3)       0         
_________________________________________________________________
block1_conv1 (Conv2D)        (None, 150, 150, 64)      1792      
_________________________________________________________________
block1_conv2 (Conv2D)        (None, 150, 150, 64)      36928     
_________________________________________________________________
block1_pool (MaxPooling2D)   (None, 75, 75, 64)        0         
_________________________________________________________________
block2_conv1 (Conv2D)        (None, 75, 75, 128)       73856     
_________________________________________________________________
block2_conv2 (Conv2D)        (None, 75, 75, 128)       147584    
_________________________________________________________________
block2_pool (MaxPooling2D)   (None, 37, 37, 128)       0         
_________________________________________________________________
block3_conv1 (Conv2D)        (None, 37, 37, 256)       295168    
_________________________________________________________________
block3_conv2 (Conv2D)        (None, 37, 37, 256)       590080    
_________________________________________________________________
block3_conv3 (Conv2D)        (None, 37, 37, 256)       590080    
_________________________________________________________________
block3_pool (MaxPooling2D)   (None, 18, 18, 256)       0         
_________________________________________________________________
block4_conv1 (Conv2D)        (None, 18, 18, 512)       1180160   
_________________________________________________________________
block4_conv2 (Conv2D)        (None, 18, 18, 512)       2359808   
_________________________________________________________________
block4_conv3 (Conv2D)        (None, 18, 18, 512)       2359808   
```

```
_________________________________________________________________
block4_pool (MaxPooling2D)   (None, 9, 9, 512)         0         
_________________________________________________________________
block5_conv1 (Conv2D)        (None, 9, 9, 512)         2359808   
_________________________________________________________________
block5_conv2 (Conv2D)        (None, 9, 9, 512)         2359808   
_________________________________________________________________
block5_conv3 (Conv2D)        (None, 9, 9, 512)         2359808   
_________________________________________________________________
block5_pool (MaxPooling2D)   (None, 4, 4, 512)         0         
=================================================================
Total params: 14,714,688
Trainable params: 14,714,688
Non-trainable params: 0
_________________________________________________________________
```

In [30]:

```
# Adding custom layers to create a new model
new_model3 = Sequential([
    model3,
    Flatten(name='flatten'),
    Dense(256, activation='relu', name='new_fc1'),
    Dense(5, activation='softmax', name='new_predictions')
])
new_model3.summary()
```

```
Model: "sequential_7"
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
vgg16 (Model)                (None, 4, 4, 512)         14714688  
_________________________________________________________________
flatten (Flatten)            (None, 8192)              0         
_________________________________________________________________
new_fc1 (Dense)              (None, 256)               2097408   
_________________________________________________________________
new_predictions (Dense)      (None, 5)                 1285      
=================================================================
Total params: 16,813,381
Trainable params: 16,813,381
Non-trainable params: 0
_________________________________________________________________
```

In [31]:
```
# Compiling the model
new_model3.compile(loss=loss, optimizer=optimizer, metrics=metrics)

# training
new_model3.fit_generator(train_generator,epochs=epochs,verbose=1, callbacks=[es])
score3 = new_model3.evaluate(test_generator, verbose=1)
printAccuracy(score3)
```

```
Epoch 1/5
138/138 [==============================] - 992s 7s/step - loss: 1.1648 - accura
cy: 0.5390
Epoch 2/5
138/138 [==============================] - 946s 7s/step - loss: 0.5879 - accura
cy: 0.7851
Epoch 00002: early stopping
46/46 [==============================] - 85s 2s/step
Test loss: 0.4552778899669647
Test accuracy: 0.7617486119270325
```

Outcome Comparison

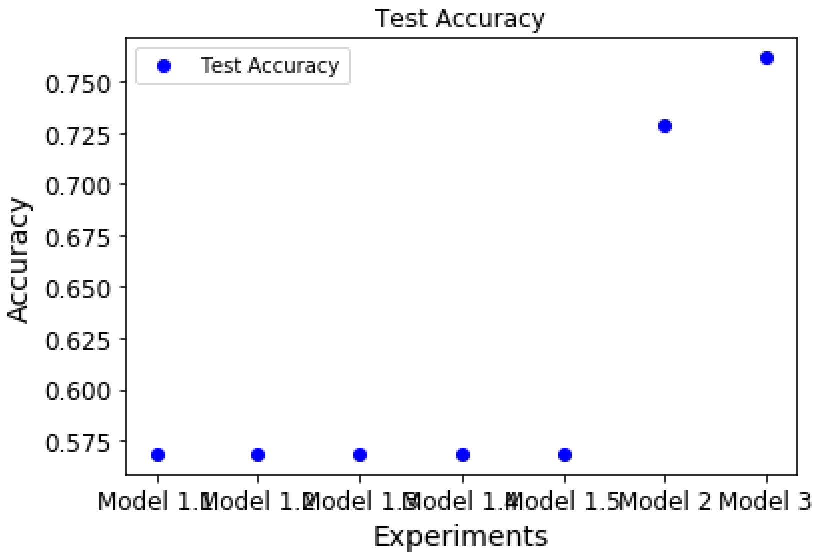
```
In [32]: experiments = ["Model 1.1","Model 1.2","Model 1.3","Model 1.4","Model 1.5","Model

         test_acc_summary = []

         test_acc_summary.append(score1[1])
         test_acc_summary.append(score1_hp2[1])
         test_acc_summary.append(score1_hp3[1])
         test_acc_summary.append(score1_hp4[1])
         test_acc_summary.append(score1_hp5[1])
         test_acc_summary.append(score2[1])
         test_acc_summary.append(score3[1])

         # "bo" is for "blue dot"
         plt.plot(experiments, test_acc_summary, 'bo', label='Test Accuracy')
         plt.title('Test Accuracy')
         plt.xlabel('Experiments')
         plt.ylabel('Accuracy')
         plt.legend()

         plt.show()
```



The better model is Model 3, because params are all trainable. This way the convolutional layers could learn the specifics of flowers data set.