MidTerm Assignment: notebook 3: Learning to drive (Total: 15pts)

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Disclaimer: Code is split in this file as per the requirements of the sub-questions.

In this notebook, we will use the Keras API (https://keras.io/) to build and train a convolutional neural network to discriminate between four types of road signs. To simplify we will consider the detection of 4 different signs:

- A '30 km/h' sign (folder 1)
- A 'Stop' sign
- A 'Go straight' sign
- A 'Keep left' sign

In [36]:
```
# <img src="learning2Drive.png" width="800" />
from IPython.display import Image
Image('learning2Drive.png')
```

Out[36]:

Import Respective Libraries

In [19]:
```
from keras.models import Sequential
from keras.layers import Dense, Conv2D, Flatten
from keras.layers import Conv2D, MaxPooling2D
import matplotlib.pyplot as plt
from keras.datasets import mnist
from keras.utils import to_categorical
import os
from sklearn.model_selection import train_test_split
import numpy as np
from tensorflow.keras.optimizers import SGD
from tensorflow.keras.optimizers import Adam
import tensorflow as tf
import cv2
from keras import optimizers
import keras
import keras.utils
from keras.optimizers import SGD
import matplotlib.image as mpimg
```

An example of each sign is given below.

In [13]:
```
def show_example():
    img1 = mpimg.imread('1/00001_00000_00012.png')
    print(img1.shape)
    plt.subplot(141)
    plt.imshow(img1)
    plt.axis('off')

    plt.subplot(142)
    img2 = mpimg.imread('2/00014_00001_00019.png')
    plt.imshow(img2)
    plt.axis('off')
    print(img2.shape)
    plt.subplot(143)
    img3 = mpimg.imread('3/00035_00008_00023.png')
    plt.imshow(img3)
    plt.axis('off')
    print(img3.shape)
    plt.subplot(144)
    img4 = mpimg.imread('4/00039_00000_00029.png')
    plt.imshow(img4)
    plt.axis('off')
    print(img4.shape)
    plt.show()
show_example()
```

```
(65, 65, 3)
(73, 73, 3)
(73, 77, 3)
(193, 188, 3)
```

Question 1 (10pts). In this exercise, you need to build and train a convolutional neural network to discriminate between the four images.

- Before building the network, you should start by cropping the images so that they all have a common predefined size (take the smallest size across all images)
- We will use a **Sequential model** from Keras but it will be up top you to define the structure of the convolution net. Initialization of the sequential model can be done with the following line

model = Sequential()

Solution

```
1. Load Data
2. Split Data into (X_train, y_train), (X_test, y_test)
3. Data Pre-processing on the Input
4. Data Pre-processing on the Output Column
5. Build the Model: Input_layer + Other convolutional layers that needs to b
e addedd
6. DO Pooling layers, Falttening, and Dense layer
7. Compile the model
8. Fit the Data
9. Output the Accuracy of the Model
```

Solution: Loading Data

```
Images from all 4 folders
```

In [14]:
```
# ======================================================================
==========
# Loading Images from 4 folders
# ======================================================================
==========

def load_images_from_folder():
    names = [1,2,3,4]
    images = []
    targets = []
    img_size = 30
    for i in names:
        # ============================================================
        # While running it on your machine, Change this directory.
        # ============================================================
        folder = "/Users/mirza/Documents/Spring '20 - Paris/Machine Lear
ning/Midterm/"+str(i)
        print("Loading images from: ",folder)

        for filename in os.listdir(folder):
            img = cv2.imread(os.path.join(folder,filename))
            if img is not None:
                img = cv2.resize(img,(img_size,img_size))
                images.append(img)
                targets.append(i)
    count = 0
    for i in images:
        count+=1
    print("Total images loaded: ",count)
    return images, targets
images, targets = load_images_from_folder()
```

```
Loading images from:  /Users/mirza/Documents/Spring '20 - Paris/Machine
Learning/Midterm/1
Loading images from:  /Users/mirza/Documents/Spring '20 - Paris/Machine
Learning/Midterm/2
Loading images from:  /Users/mirza/Documents/Spring '20 - Paris/Machine
Learning/Midterm/3
Loading images from:  /Users/mirza/Documents/Spring '20 - Paris/Machine
Learning/Midterm/4
Total images loaded:  4500
```

1.a. Convolutions.

- We will defintely use **convolutional layers**. you can add such layers to the model by using the lines

```
  model.add(Conv2D(num_units, (filter_size1, filter_size2), padding='sam
e',
                     input_shape=(3, IMG_SIZE, IMG_SIZE),
                     activation='relu'))
```

for the first layer and

```
model.add(Conv2D(filters, filter_size, activation, input_shape)
```

for all the others. 'filters' indicate the number of filters you want to use in the convolutional layer. filter*size is the size of each filter and activation is the usual activation that comes on top of the convolution, i.e. $x*{\text{out}} = \sigma(\text{filter}*\text{input})$. Finally input_shape indicates the size of your input. Note that only the input layer should be given the input size. Subsequent layers will automatically compute the size of their inputs based on previous layers.

Solution

Split Data into Train and Test

Images loaded in above function are split into Train and Test sub data sets

In [15]:
```
# ======================================================================
==========
# Split Data
# ======================================================================
==========

def dataset_split(X,t):

    X_train, X_test, y_train, y_test = train_test_split(X, t, train_size
=0.90,test_size=0.10, random_state=101)

    c = 0
    for i in y_train:
        c+=1

    d = 0
    for j in y_test:
        d+=1

    X_train = np.asarray(X_train)
    X_test = np.asarray(X_test)
    print("Training Set: {} \nTest Set: {} \nTotal Data: {}".format(c,d,
c+d))
    return X_train, X_test, y_train, y_test

X_train, X_test, y_train, y_test = dataset_split(images, targets)
```

```
Training Set: 4050
Test Set: 450
Total Data: 4500
```

In [16]:
```
# ======================================================================
==========
# Verify
# ======================================================================
==========

# print(X_train[2])
print(X_train[2].shape)
```

```
(30, 30, 3)
```

In [17]:
```
# ======================================================================
==========
# Verify
# ======================================================================
==========

print(y_train[:30])
```

```
[1, 3, 2, 3, 2, 3, 3, 1, 3, 1, 2, 2, 3, 1, 1, 1, 1, 2, 1, 1, 3, 1, 1,
1, 3, 1, 3, 3, 3, 2]
```

Solution

Data Pre-processing on Input and Output Vectors:

A. Reshape the size of all images to fit the Model

In [20]:
```
# ======================================================================
==========
#reshape data to fit model
# ======================================================================
==========

def pre_processing(X_train, X_test, y_train, y_test):

    num_of_images_X_train = 3375
    num_of_images_X_test = 1125
    img_size = 30
    image_grayscale = 1

#     X_train = X_train.reshape((num_of_images_X_train, img_size, img_si
ze, image_grayscale))
#     X_test = X_test.reshape((num_of_images_X_test, img_size, img_size,
image_grayscale))

    X_train = tf.keras.utils.normalize(X_train)
    X_test = tf.keras.utils.normalize(X_test)

    y_train = to_categorical(y_train)
    y_test = to_categorical(y_test)

    return X_train, X_test, y_train, y_test

X_train, X_test, y_train, y_test = pre_processing(X_train, X_test, y_tra
in, y_test)
```

In [21]:
```
# ======================================================================
==========
# Verify Data Pre-Processing
# ======================================================================
==========

print(X_train[2].shape)
print(y_train[2])
```

```
(30, 30, 3)
[0. 0. 1. 0. 0.]
```

Solution

Buidling Model

```
                model.add(Conv2D(num_units, (filter_size1, filter_size2), pa
dding='same',
                         input_shape=(3, IMG_SIZE, IMG_SIZE),
                         activation='relu'))
     __Description__
                num_units = num of nodes in each layer
                filter_size = filter matrix of our convolution i.e. kernel_s
ize
                input_shape = size of the image
                activation = activation function being used
```

[Documentation (https://keras.io/layers/convolutional/)](https://keras.io/layers/convolutional/) For this model

In [22]:
```
# ========================================================================
==========
# Model Building
# ========================================================================
==========
model = Sequential()

img_size = 30
image_grayscale= 3

num_units = 100
num_units_later = num_units//2
filter_size = (3, 3)

# # Add input Layer
model.add(Conv2D(num_units, kernel_size=(3,3), activation='relu', input_
shape=(img_size,img_size,image_grayscale)))


# # Add second layer
model.add(Conv2D(num_units_later, kernel_size=(3,3), activation='relu'))

# Adding a Pool Layer
model.add(MaxPooling2D(pool_size=filter_size, strides=None, padding='val
id', data_format=None))

# # Add third layer but with lesser units
model.add(Conv2D(num_units_later, kernel_size=3, activation='relu'))

model.summary()
```

```
Model: "sequential_1"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_1 (Conv2D)            (None, 28, 28, 100)       2800
_________________________________________________________________
conv2d_2 (Conv2D)            (None, 26, 26, 50)        45050
_________________________________________________________________
max_pooling2d_1 (MaxPooling2 (None, 8, 8, 50)          0
_________________________________________________________________
conv2d_3 (Conv2D)            (None, 6, 6, 50)          22550
=================================================================
Total params: 70,400
Trainable params: 70,400
Non-trainable params: 0
_________________________________________________________________
```

1.b Pooling Layers

On top of the convolutional layers, convolutional neural networks (CNN) also often rely on **Pooling layers**. The addition of such a layer can be done through the following line

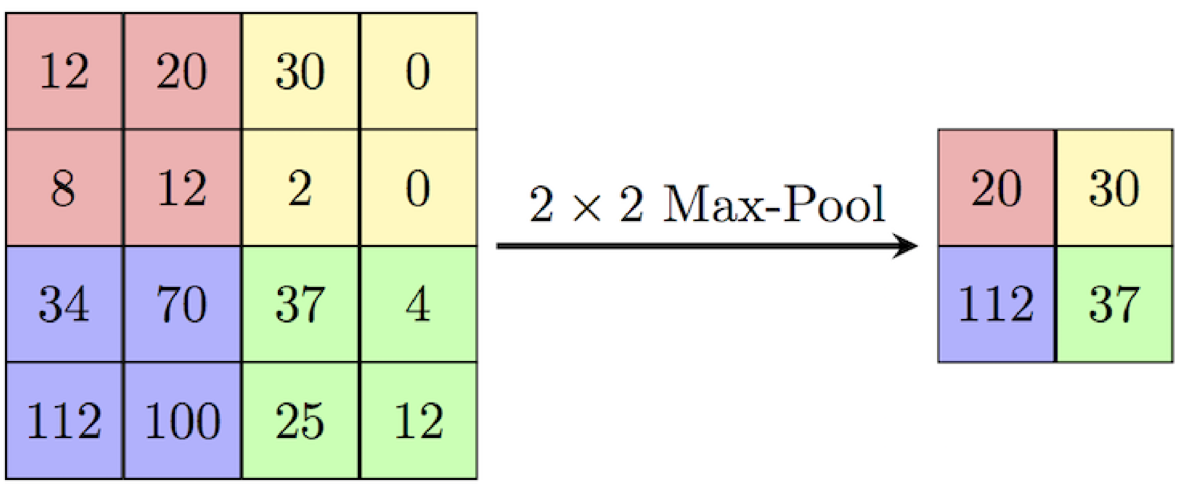
```
model.add(MaxPooling2D(pool_size=(filter_sz1, filter_sz2)))
```

The *pooling layers* usually come with two parameters: the 'pool size' and the 'stride' parameter. The basic choice for the pool size is (2,2) and the stride is usually set to None (which means it will split the image into non overlapping regions such as in the Figure below). You should however feel free to play a little with those parameters. The **MaxPool operator** considers a mask of size pool_size which is slided over the image by a number of pixels equal to the stride parameters (in x and y, there are hence two translation parameters). for each position of the mask, the output only retains the max of the pixels appearing in the mask (This idea is illustrated below). One way to understand the effect of the pooling operator is that if the filter detects an edge in a subregion of the image (thus returning at least one large value), although a MaxPooling will reduce the number of parameters, it will keep track of this information.

Adding 'Maxpooling' layers is known to work well in practice.

In [38]:
```
#<img src="Maxpool.png" width=600/>
Image('Maxpool.png')
```

Out[38]:



Although it is a little bit up to you to decide how you want to structure the network, a good start is to add a couple (definitely not exceeding 4) combinations (convolution, convolution, Pooling) with increasing number of units (you do every power of two like 16, 32, 128,...).

Solution

Pooling Layer

In [23]:
```
# ======================================================================
==========
# Add Pool Layer
# ======================================================================
==========

model.add(MaxPooling2D(pool_size=(3,3), strides=None, padding='valid', d
ata_format=None))

model.summary()
```

```
Model: "sequential_1"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_1 (Conv2D)            (None, 28, 28, 100)       2800
_________________________________________________________________
conv2d_2 (Conv2D)            (None, 26, 26, 50)        45050
_________________________________________________________________
max_pooling2d_1 (MaxPooling2 (None, 8, 8, 50)          0
_________________________________________________________________
conv2d_3 (Conv2D)            (None, 6, 6, 50)          22550
_________________________________________________________________
max_pooling2d_2 (MaxPooling2 (None, 2, 2, 50)          0
=================================================================
Total params: 70,400
Trainable params: 70,400
Non-trainable params: 0
_________________________________________________________________
```

1.c. Flattening and Fully connected layers

Once you have stacked the convolutional and pooling layers, you should flatten the output through a line of the form

```
model.add(Flatten())
```

And add a couple (no need to put more than 2,3) dense fully connected layers through lines of the form

```
model.add(Dense(num_units, activation='relu'))
```

Solution: Flattening and Densing

```
1. Flatten serves as a connection between the convolution and dense layers
2. ‘Dense’ is the layer type we will use in for our output layer
```

In [24]:
```
# ======================================================================
==========
# Flattening and Densing
# ======================================================================
==========

model.add(Flatten())
model.add(Dense(num_units, activation= 'relu'))

model.summary()
```

```
Model: "sequential_1"
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
conv2d_1 (Conv2D)            (None, 28, 28, 100)       2800      
_________________________________________________________________
conv2d_2 (Conv2D)            (None, 26, 26, 50)        45050     
_________________________________________________________________
max_pooling2d_1 (MaxPooling2 (None, 8, 8, 50)          0         
_________________________________________________________________
conv2d_3 (Conv2D)            (None, 6, 6, 50)          22550     
_________________________________________________________________
max_pooling2d_2 (MaxPooling2 (None, 2, 2, 50)          0         
_________________________________________________________________
flatten_1 (Flatten)          (None, 200)               0         
_________________________________________________________________
dense_1 (Dense)              (None, 100)               20100     
=================================================================
Total params: 90,500
Trainable params: 90,500
Non-trainable params: 0
_________________________________________________________________
```

1.d. Concluding

Since there are four possible signs, you need to **finish your network with a dense layer with 4 units.** Each of those units should output four number between 0 and 1 representing the likelihood that any of the four sign is detected and such that $p_1 + p_2 + p_3 + p_4 = 1$ (hopefully with one probability much larger than the others). For this reason, a good choice for the **final activation function** of those four units is the **softmax** (Why?).

Solution

WHY Softmax?

```
  1. Softmax is sort of Multi Class Sigmoid where the sum of all softmax uni
ts is 1. Increasing the output
  value of one class makes the the others go down (sigma=1)

  2. At the final layer of a neural network, the model produces its final ac
tivations (a.k.a. logits), which
     we would like to be able to interpret as probabilities, as that would a
llow is to e.g. create a
     classification result

  3. the reason for using the softmax is to ensure these logits all sum up t
o 1, thereby fulfilling the
     constraints of a probability density
```

In [25]:
```
# ======================================================================
==========
# Softmax Densing
# ======================================================================
==========

num_outputs = 5
model.add(Dense(num_outputs, activation='softmax'))
model.summary()
```

```
Model: "sequential_1"
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
conv2d_1 (Conv2D)            (None, 28, 28, 100)       2800      
_________________________________________________________________
conv2d_2 (Conv2D)            (None, 26, 26, 50)        45050     
_________________________________________________________________
max_pooling2d_1 (MaxPooling2 (None, 8, 8, 50)          0         
_________________________________________________________________
conv2d_3 (Conv2D)            (None, 6, 6, 50)          22550     
_________________________________________________________________
max_pooling2d_2 (MaxPooling2 (None, 2, 2, 50)          0         
_________________________________________________________________
flatten_1 (Flatten)          (None, 200)               0         
_________________________________________________________________
dense_1 (Dense)              (None, 100)               20100     
_________________________________________________________________
dense_2 (Dense)              (None, 5)                 505       
=================================================================
Total params: 91,005
Trainable params: 91,005
Non-trainable params: 0
_________________________________________________________________
```

Question 2 (3pts). Setting up the optimizer

Once you found a good architecture for your network, split the dataset, by retaining about 90% of the images for training and 10% of each folder for test. To train your network in Keras, we need two more steps. The first step is to set up the optimizer. Here again it is a little bit up to you to decide how you want to set up the optimization. Two popular approaches are **SGD and ADAM**. You will get to choose the learning rate. This rate should however be between 1e-3 and 1e-2. Once you have set up the optimizer, we need to set up the optimization parameters. This includes the loss (we will take it to be the **categorical cross entropy** which is the extension of the log loss to the multiclass problem).

Solution

1. "Split the Dataset" part of the Question has been done in function above: $dataset - split(X, t)$
2. The following Compiles the model with Optimizer as either SGD or ADAM with learning rate = e^{-3}

In [26]:
```
# ==========================================================================
==========
# Compiler
# ==========================================================================
==========

batch_size = 32
epochs = 3

SGD = keras.optimizers.SGD(learning_rate=0.01, momentum=0.0, nesterov=Fa
lse)
Adam = keras.optimizers.Adam(learning_rate=0.001, beta_1=0.9, beta_2=0.9
99, amsgrad=False)

Myoptimizer = [SGD, Adam]

# ==========================================================================
==========
# Change the Index of Myoptimizer to use a different Optimizer
# ==========================================================================
==========
model.compile(loss='categorical_crossentropy',optimizer=Myoptimizer[1],
metrics=['accuracy'])
```

Question 3 (2pts). Optimization

The last step is to fit the network to your data. Just as any other function in scikit-learn, we use a call to the function 'fit'. The training of neural networks can be done by splitting the dataset into minibatches and using a different batch at each SGD step. This process is repeated over the whole dataset. A complete screening of the dataset is called an epoch. We can then repeat this idea several times. In keras the number of epochs is stored in the 'epochs' parameter and the batch size is stored in the 'batch_size'.

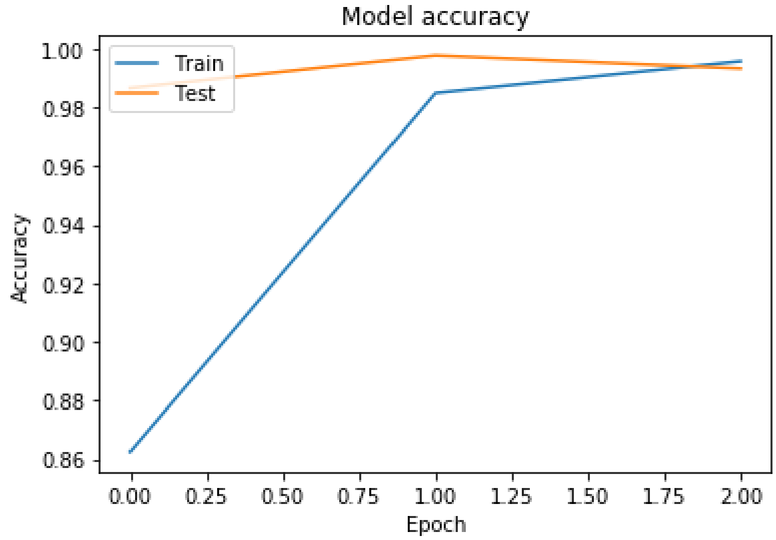
Solution

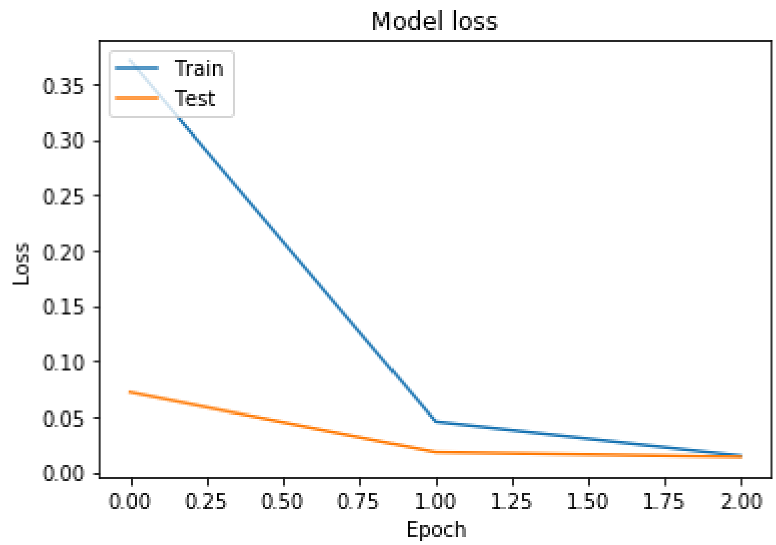
1. Model compiled is fit to the training data set with validated against the test data set
2. Accuracy of the Model is graphed below
3. Accuracy of the test dataset is also calculated

In [27]:
```
# ========================================================================
==========
# Model Fit
# ========================================================================
==========

history = model.fit(X_train, y_train, batch_size=32, validation_data=(X_
test, y_test), epochs=epochs)

# ========================================================================
==========
# Test Dataset is Evaluated
# ========================================================================
==========
test_loss, test_acc = model.evaluate(X_test,  y_test, verbose=2)
print("Accuracy of Test Dataset: {} i.e. {} %".format(test_acc, test_acc
*100))
```

```
Train on 4050 samples, validate on 450 samples
Epoch 1/3
4050/4050 [==============================] - 29s 7ms/step - loss: 0.371
1 - accuracy: 0.8625 - val_loss: 0.0718 - val_accuracy: 0.9867
Epoch 2/3
4050/4050 [==============================] - 27s 7ms/step - loss: 0.045
4 - accuracy: 0.9849 - val_loss: 0.0180 - val_accuracy: 0.9978
Epoch 3/3
4050/4050 [==============================] - 27s 7ms/step - loss: 0.014
7 - accuracy: 0.9958 - val_loss: 0.0137 - val_accuracy: 0.9933
Accuracy of Test Dataset: 0.9933333396911621 i.e. 99.33333396911621 %
```

In [28]:
```
# ======================================================================
==========
# Graph Accuracy
# ======================================================================
==========

# Plot training & validation accuracy values
plt.plot(history.history['accuracy'])
plt.plot(history.history['val_accuracy'])
plt.title('Model accuracy')
plt.ylabel('Accuracy')
plt.xlabel('Epoch')
plt.legend(['Train', 'Test'], loc='upper left')
plt.show()

# Plot training & validation loss values
plt.plot(history.history['loss'])
plt.plot(history.history['val_loss'])
plt.title('Model loss')
plt.ylabel('Loss')
plt.xlabel('Epoch')
plt.legend(['Train', 'Test'], loc='upper left')
plt.show()
```





In [29]:
```
# Verify
print(y_test[2])

# Predict
pred = model.predict(X_test)
print(pred[2])
pred[2].sum()
```

```
[0. 0. 1. 0. 0.]
[7.3136114e-10 4.4054681e-04 9.9955946e-01 7.9996845e-09 5.8797794e-10]
```

Out[29]:
```
1.0
```

Solution All-together:

This following Cells Contains Same Code but at one Place to make better sense

In [31]:
```
from keras.models import Sequential
from keras.layers import Dense, Conv2D, Flatten
from keras.layers import Conv2D, MaxPooling2D
import matplotlib.pyplot as plt
from keras.datasets import mnist
from keras.utils import to_categorical
import os
from sklearn.model_selection import train_test_split
import numpy as np
from tensorflow.keras.optimizers import SGD
from tensorflow.keras.optimizers import Adam

# ============================= Load Data ===============================
=====================

# Loading Images from 4 folders
def load_images_from_folder():
    names = [1,2,3,4]
    img_size = 30
    images = []
    targets = []
    for i in names:
        # ===========================================================
        # While running it on your machine, Change this directory.
        # ===========================================================
        folder = "/Users/mirza/Documents/Spring '20 - Paris/Machine Lear
ning/Midterm/"+str(i)
        print("Loading images from: ",folder)

        for filename in os.listdir(folder):
            img = cv2.imread(os.path.join(folder,filename))
            if img is not None:
                img = cv2.resize(img,(img_size,img_size))
                images.append(img)
                targets.append(i)
    count = 0
    for i in images:
        count+=1
    print("Total images loaded: ",count)
    return images, targets
images, targets = load_images_from_folder()

# ============================= Train_Test_Split =======================
============================

def dataset_split(X,t):

    X_train, X_test, y_train, y_test = train_test_split(X, t, train_size
=0.90,test_size=0.10, random_state=101)

    c = 0
    for i in y_train:
        c+=1

    d = 0
    for j in y_test:
```

```
        d+=1

    X_train = np.asarray(X_train)
    X_test = np.asarray(X_test)
    print("Training Set: {} \nTest Set: {} \nTotal Data: {}".format(c,d,
c+d))
    return X_train, X_test, y_train, y_test

X_train, X_test, y_train, y_test = dataset_split(images, targets)

# ============================= Data Pre-Processing ====================
===============================
#reshape data to fit model
def pre_processing(X_train, X_test, y_train, y_test):

#     X_train = X_train.reshape((num_of_images_X_train, img_size, img_si
ze, image_grayscale))
#     X_test = X_test.reshape((num_of_images_X_test, img_size, img_size,
image_grayscale))
    X_train = tf.keras.utils.normalize(X_train)
    X_test = tf.keras.utils.normalize(X_test)

    y_train = to_categorical(y_train)
    y_test = to_categorical(y_test)

    return X_train, X_test, y_train, y_test

X_train, X_test, y_train, y_test = pre_processing(X_train, X_test, y_tra
in, y_test)
```

```
Loading images from:  /Users/mirza/Documents/Spring '20 - Paris/Machine
Learning/Midterm/1
Loading images from:  /Users/mirza/Documents/Spring '20 - Paris/Machine
Learning/Midterm/2
Loading images from:  /Users/mirza/Documents/Spring '20 - Paris/Machine
Learning/Midterm/3
Loading images from:  /Users/mirza/Documents/Spring '20 - Paris/Machine
Learning/Midterm/4
Total images loaded:  4500
Training Set: 4050
Test Set: 450
Total Data: 4500
```

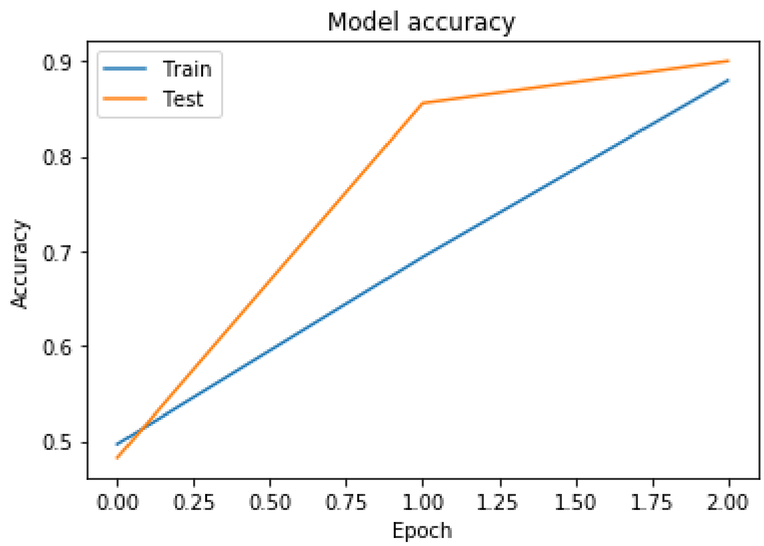
In [32]:
```
# ============================ Model Building ========================================================================
model = Sequential()

img_size = 30
image_grayscale= 3

num_units = 100
num_units_later = num_units//2
filter_size = (3, 3)

# # Add input Layer
model.add(Conv2D(num_units, kernel_size=(3,3), activation='relu', input_shape=(img_size,img_size,image_grayscale)))

model.add(MaxPooling2D(pool_size=filter_size, strides=None, padding='valid', data_format=None))

# # Add second layer
model.add(Conv2D(num_units_later, kernel_size=(3,3), activation='relu'))

# model.add(MaxPooling2D(pool_size=filter_size, strides=None, padding='valid', data_format=None))

# # Add third layer but with lesser units
# model.add(Conv2D(num_units_later, kernel_size=2, activation='relu'))

model.add(MaxPooling2D(pool_size=(3,3), strides=None, padding='valid', data_format=None))

model.add(Flatten())
# model.add(Dense(num_units, activation= 'relu'))
model.add(Dense(num_units_later, activation='relu'))

num_outputs = 5
model.add(Dense(num_outputs, activation='softmax'))

model.summary()
```

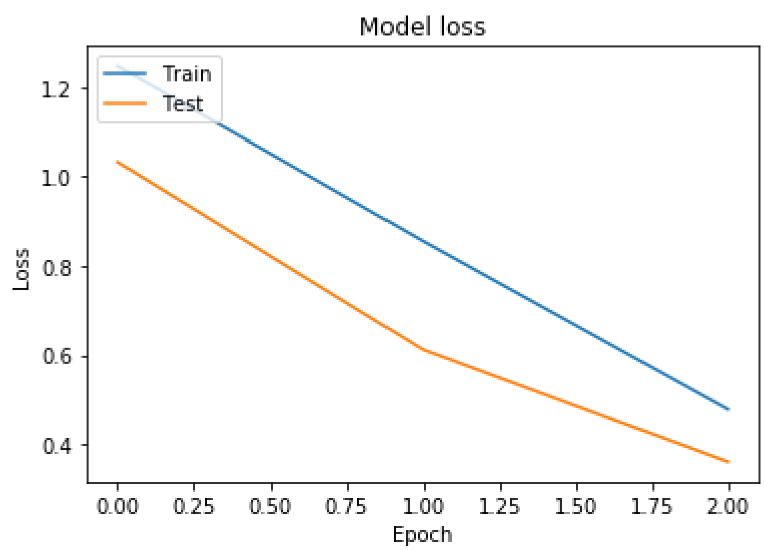
```
Model: "sequential_2"
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
conv2d_4 (Conv2D)            (None, 28, 28, 100)       2800      
_________________________________________________________________
max_pooling2d_3 (MaxPooling2 (None, 9, 9, 100)         0         
_________________________________________________________________
conv2d_5 (Conv2D)            (None, 7, 7, 50)          45050     
_________________________________________________________________
max_pooling2d_4 (MaxPooling2 (None, 2, 2, 50)          0         
_________________________________________________________________
flatten_2 (Flatten)          (None, 200)               0         
_________________________________________________________________
dense_3 (Dense)              (None, 50)                10050     
_________________________________________________________________
dense_4 (Dense)              (None, 5)                 255       
=================================================================
Total params: 58,155
Trainable params: 58,155
Non-trainable params: 0
_________________________________________________________________
```

Used SGD Optimizer unlike above model

In [33]:
```
# ============================= Compiler ================================
====================

batch_size = 100
epochs = 3

SGD = keras.optimizers.SGD(learning_rate=0.01, momentum=0.0, nesterov=Fa
lse)
Adam = keras.optimizers.Adam(learning_rate=0.001, beta_1=0.9, beta_2=0.9
99, amsgrad=False)
Myoptimizer = [SGD, Adam]

model.compile(loss='categorical_crossentropy',optimizer=Myoptimizer[0],
metrics=['accuracy'])
history = model.fit(X_train, y_train, batch_size=32, validation_data=(X_
test, y_test), epochs=epochs)

test_loss, test_acc = model.evaluate(X_test,  y_test, verbose=2)
print("Accuracy of Test Dataset: {} i.e. {} %".format(test_acc, test_acc
*100))
# ========================================================================
==========
# Graph Accuracy
# ========================================================================
==========

# Plot training & validation accuracy values
plt.plot(history.history['accuracy'])
plt.plot(history.history['val_accuracy'])
plt.title('Model accuracy')
plt.ylabel('Accuracy')
plt.xlabel('Epoch')
plt.legend(['Train', 'Test'], loc='upper left')
plt.show()

# Plot training & validation loss values
plt.plot(history.history['loss'])
plt.plot(history.history['val_loss'])
plt.title('Model loss')
plt.ylabel('Loss')
plt.xlabel('Epoch')
plt.legend(['Train', 'Test'], loc='upper left')
plt.show()
```

```
Train on 4050 samples, validate on 450 samples
Epoch 1/3
4050/4050 [==============================] - 23s 6ms/step - loss: 1.247
8 - accuracy: 0.4965 - val_loss: 1.0328 - val_accuracy: 0.4822
Epoch 2/3
4050/4050 [==============================] - 22s 6ms/step - loss: 0.855
9 - accuracy: 0.6936 - val_loss: 0.6123 - val_accuracy: 0.8556
Epoch 3/3
4050/4050 [==============================] - 22s 6ms/step - loss: 0.478
3 - accuracy: 0.8795 - val_loss: 0.3607 - val_accuracy: 0.9000
Accuracy of Test Dataset: 0.8999999761581421 i.e. 89.99999761581421 %
```





In [34]:
```
# Verify
print(y_test[2])

# Predict
pred = model.predict(X_test)
print(pred[2])
pred[2].sum()
```

```
[0. 0. 1. 0. 0.]
[5.3129585e-05 3.4639250e-02 9.6361095e-01 7.5610733e-05 1.6210735e-03]
```

Out[34]:
```
1.0000001
```

If there is any issue, rerun the cells or clear the outputs of the cell before running them

First Model is with ADAM Optimizer. Second Model is with SDG Optimizer

End of Code