smai_assignment_2_q_1_2_report

April 8, 2018

0.1 CNN Computations on Cifar-10 Dataset

Load Cifar-10 data Downloading data from https://www.cs.toronto.edu/~kriz/cifar-10-python.tar.gz
170500096/170498071 [==============================] - 16s 0us/step

Training Data

In [3]:

```
Training data:
Number of examples:  50000
Number of channels: 3
Image size: 32 32


Test data:
Number of examples: 10000
Number of channels: 3
Image size: 32 32
```

Visualize some images from CIFAR-10 dataset. It contains 10 classes namely, airplane, automobile, bird, cat, deer, dog, frog, horse, ship, truck

In [5]:

Normalize the data.

In [4]:

```
mean before normalization: 120.70756512369792
std before normalization: 64.1500758911213
mean after normalization: 4.91799193961621e-17
std after normalization: 0.9999999999999996
```

Training Parameters Training Batch Size (batchSize) = 50
Number of classes in CIFAR-10 dataset (num_classes) = 10
Number of epochs for training (num_epochs) = 50
Learning rate for the network (learningRate) = 0.001
Learning weight decay. Reduce the learn rate by 0.95 after epoch (lr_weight_decay) = 0.95
input image dimensions (img_rows, img_cols) = 32, 32

Model Summary

In [7]:

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_1 (Conv2D)            (None, 28, 28, 6)         456
_________________________________________________________________
```

```
activation_1 (Activation)    (None, 28, 28, 6)         0
_________________________________________________________________
max_pooling2d_1 (MaxPooling2 (None, 14, 14, 6)         0
_________________________________________________________________
conv2d_2 (Conv2D)            (None, 10, 10, 16)        2416
_________________________________________________________________
activation_2 (Activation)    (None, 10, 10, 16)        0
_________________________________________________________________
max_pooling2d_2 (MaxPooling2 (None, 5, 5, 16)          0
_________________________________________________________________
flatten_1 (Flatten)          (None, 400)               0
_________________________________________________________________
dense_1 (Dense)              (None, 120)               48120
_________________________________________________________________
activation_3 (Activation)    (None, 120)               0
_________________________________________________________________
dense_2 (Dense)              (None, 84)                10164
_________________________________________________________________
activation_4 (Activation)    (None, 84)                0
_________________________________________________________________
dense_3 (Dense)              (None, 10)                850
_________________________________________________________________
activation_5 (Activation)    (None, 10)                0
=================================================================
Total params: 62,006
Trainable params: 62,006
Non-trainable params: 0
_________________________________________________________________
None
```

Compile and then train the network

In [8]:

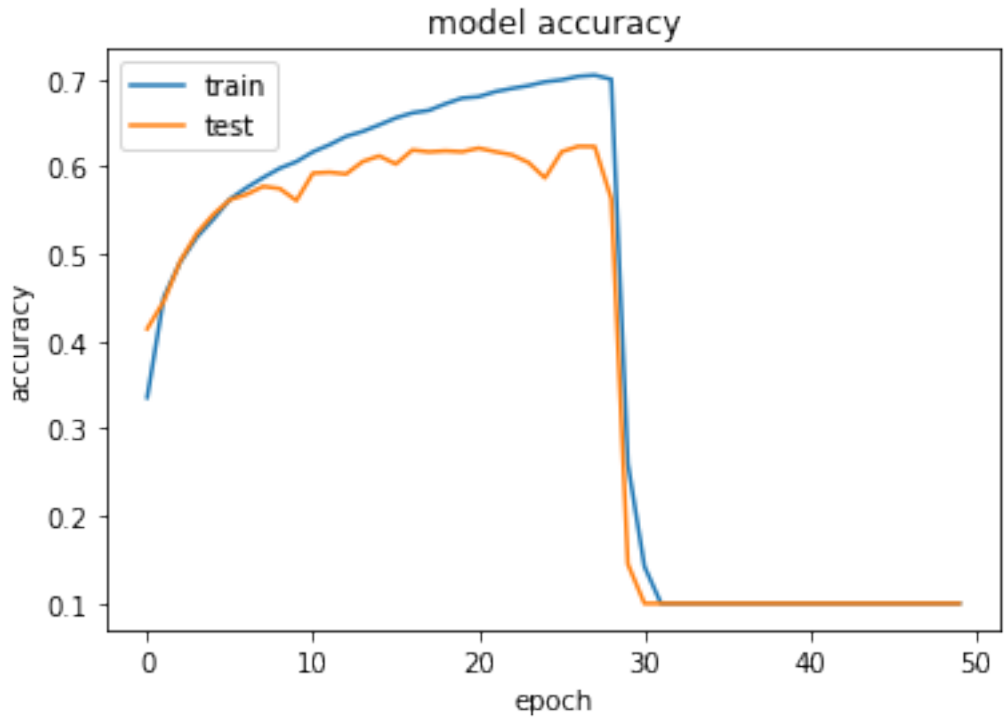
```
Train on 50000 samples, validate on 10000 samples
Epoch 1/50
50000/50000 [==============================] - 41s 814us/step - loss: 1.8241 - acc: 0.3356 - va
Epoch 2/50
50000/50000 [==============================] - 41s 819us/step - loss: 1.5212 - acc: 0.4504 - va
Epoch 3/50
50000/50000 [==============================] - 43s 869us/step - loss: 1.4198 - acc: 0.4907 - va
Epoch 4/50
50000/50000 [==============================] - 40s 810us/step - loss: 1.3469 - acc: 0.5191 - va
Epoch 5/50
50000/50000 [==============================] - 40s 803us/step - loss: 1.2902 - acc: 0.5398 - va
Epoch 6/50
50000/50000 [==============================] - 41s 813us/step - loss: 1.2395 - acc: 0.5626 - va
```

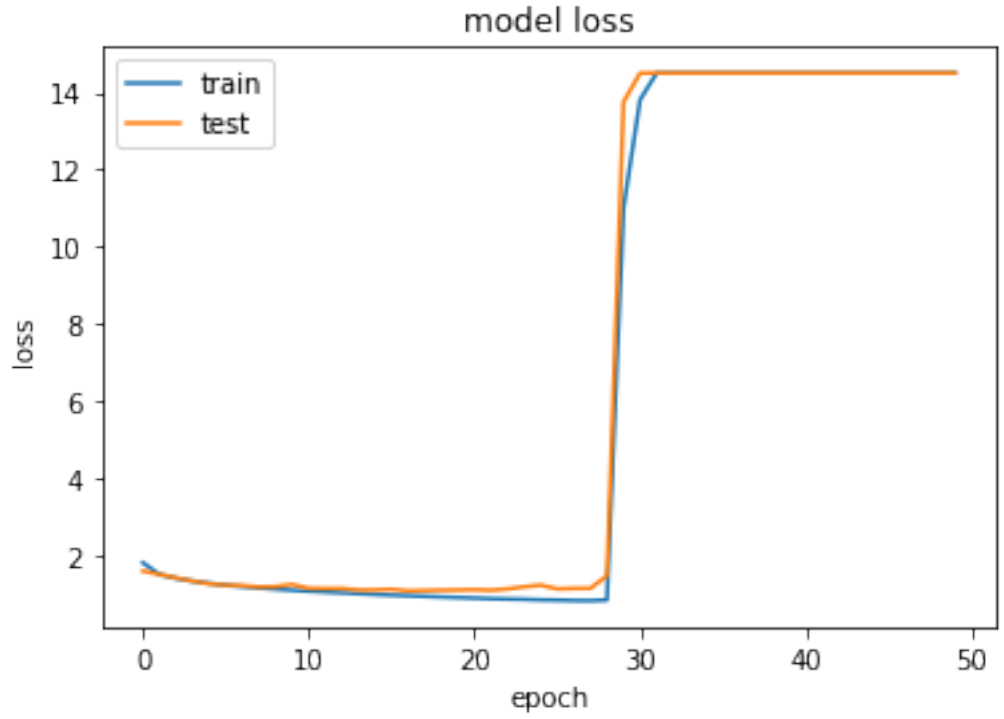
```
Epoch 7/50
50000/50000 [==============================] - 42s 830us/step - loss: 1.2048 - acc: 0.5757 - va
Epoch 8/50
50000/50000 [==============================] - 42s 842us/step - loss: 1.1703 - acc: 0.5872 - va
Epoch 9/50
50000/50000 [==============================] - 42s 848us/step - loss: 1.1389 - acc: 0.5978 - va
Epoch 10/50
50000/50000 [==============================] - 43s 857us/step - loss: 1.1129 - acc: 0.6054 - va
Epoch 11/50
50000/50000 [==============================] - 43s 864us/step - loss: 1.0869 - acc: 0.6166 - va
Epoch 12/50
50000/50000 [==============================] - 44s 871us/step - loss: 1.0665 - acc: 0.6247 - va
Epoch 13/50
50000/50000 [==============================] - 45s 892us/step - loss: 1.0443 - acc: 0.6343 - va
Epoch 14/50
50000/50000 [==============================] - 46s 923us/step - loss: 1.0234 - acc: 0.6400 - va
Epoch 15/50
50000/50000 [==============================] - 46s 913us/step - loss: 1.0027 - acc: 0.6475 - va
Epoch 16/50
50000/50000 [==============================] - 46s 924us/step - loss: 0.9853 - acc: 0.6554 - va
Epoch 17/50
50000/50000 [==============================] - 47s 941us/step - loss: 0.9688 - acc: 0.6612 - va
Epoch 18/50
50000/50000 [==============================] - 48s 959us/step - loss: 0.9530 - acc: 0.6641 - va
Epoch 19/50
50000/50000 [==============================] - 49s 972us/step - loss: 0.9369 - acc: 0.6717 - va
Epoch 20/50
50000/50000 [==============================] - 49s 977us/step - loss: 0.9229 - acc: 0.6781 - va
Epoch 21/50
50000/50000 [==============================] - 50s 992us/step - loss: 0.9086 - acc: 0.6797 - va
Epoch 22/50
50000/50000 [==============================] - 50s 1ms/step - loss: 0.8930 - acc: 0.6855 - val_
Epoch 23/50
50000/50000 [==============================] - 51s 1ms/step - loss: 0.8828 - acc: 0.6892 - val_
Epoch 24/50
50000/50000 [==============================] - 51s 1ms/step - loss: 0.8750 - acc: 0.6923 - val_
Epoch 25/50
50000/50000 [==============================] - 51s 1ms/step - loss: 0.8606 - acc: 0.6968 - val_
Epoch 26/50
50000/50000 [==============================] - 52s 1ms/step - loss: 0.8555 - acc: 0.6989 - val_
Epoch 27/50
50000/50000 [==============================] - 52s 1ms/step - loss: 0.8444 - acc: 0.7029 - val_
Epoch 28/50
50000/50000 [==============================] - 53s 1ms/step - loss: 0.8414 - acc: 0.7043 - val_
Epoch 29/50
50000/50000 [==============================] - 53s 1ms/step - loss: 0.8588 - acc: 0.6996 - val_
Epoch 30/50
50000/50000 [==============================] - 53s 1ms/step - loss: 11.0207 - acc: 0.2600 - val
```

```
Epoch 31/50
50000/50000 [==============================] - 53s 1ms/step - loss: 13.8178 - acc: 0.1423 - val
Epoch 32/50
50000/50000 [==============================] - 52s 1ms/step - loss: 14.5056 - acc: 0.1000 - val
Epoch 33/50
50000/50000 [==============================] - 53s 1ms/step - loss: 14.5056 - acc: 0.1000 - val
Epoch 34/50
50000/50000 [==============================] - 53s 1ms/step - loss: 14.5056 - acc: 0.1000 - val
Epoch 35/50
50000/50000 [==============================] - 53s 1ms/step - loss: 14.5056 - acc: 0.1000 - val
Epoch 36/50
50000/50000 [==============================] - 53s 1ms/step - loss: 14.5056 - acc: 0.1000 - val
Epoch 37/50
50000/50000 [==============================] - 53s 1ms/step - loss: 14.5056 - acc: 0.1000 - val
Epoch 38/50
50000/50000 [==============================] - 53s 1ms/step - loss: 14.5056 - acc: 0.1000 - val
Epoch 39/50
50000/50000 [==============================] - 53s 1ms/step - loss: 14.5056 - acc: 0.1000 - val
Epoch 40/50
50000/50000 [==============================] - 53s 1ms/step - loss: 14.5056 - acc: 0.1000 - val
Epoch 41/50
50000/50000 [==============================] - 53s 1ms/step - loss: 14.5056 - acc: 0.1000 - val
Epoch 42/50
50000/50000 [==============================] - 53s 1ms/step - loss: 14.5056 - acc: 0.1000 - val
Epoch 43/50
50000/50000 [==============================] - 53s 1ms/step - loss: 14.5056 - acc: 0.1000 - val
Epoch 44/50
50000/50000 [==============================] - 53s 1ms/step - loss: 14.5056 - acc: 0.1000 - val
Epoch 45/50
50000/50000 [==============================] - 53s 1ms/step - loss: 14.5056 - acc: 0.1000 - val
Epoch 46/50
50000/50000 [==============================] - 53s 1ms/step - loss: 14.5056 - acc: 0.1000 - val
Epoch 47/50
50000/50000 [==============================] - 53s 1ms/step - loss: 14.5056 - acc: 0.1000 - val
Epoch 48/50
50000/50000 [==============================] - 53s 1ms/step - loss: 14.5056 - acc: 0.1000 - val
Epoch 49/50
50000/50000 [==============================] - 53s 1ms/step - loss: 14.5056 - acc: 0.1000 - val
Epoch 50/50
50000/50000 [==============================] - 53s 1ms/step - loss: 14.5056 - acc: 0.1000 - val
```

Print the scores

In [9]:


model accuracy
train
test
accuracy
epoch
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
10
20
30
40
50


model loss
train
test
loss
epoch
14
12
10
8
6
4
2
0
10
20
30
40
50

Test the network

In [10]:

```
Test score: 14.506285668945312
Test accuracy: 0.1
```

** Q1: [0.5 point] **

What are the number of parameters in convolution layers with K filters each of size 3*w*h.

** A1: **

3 x w x h x K weights and K biases

** Q2: [0.5 points] **

What are the number of parameters in a max pooling operation?

** A2: **

The max-pooling layers just replace a 2x2 neighborhood by its maximum value. So there are NO parameters needed to be learnt in a pooling layer.

Q3: [0.5 point]

Which of the operations contain most number of parameters? (a) conv (b) pool (c) Fully connected layer (FC) (d) Relu

** A3: **

The highest number of parameters are learnt in Fully Connected Layer.

Q4: [0.5 point]

Which operation consume most amount of memory? (a) initial convolution layers (b) fully connected layers at the end

** A4: **

Huge amount of memory is consumed in the initial convolution layers as it has to remember all the images with various of channels.

** Q5: [2 points] **

Experiment with **learning rate** (learningRate) and notice the behaviour of the learning process. Plot your observations in a graph with brief explanation. Take the values on a log scale. Vary only one parameter at a time.

Observations

1. As the learning rate increases the model takes more time (no of epochs) to converge 2. If the learning rate is very large then the training might not even converge. 3. A carefull choice of learning is very important int training neural networks.

Graphs shown below in support of the observations.

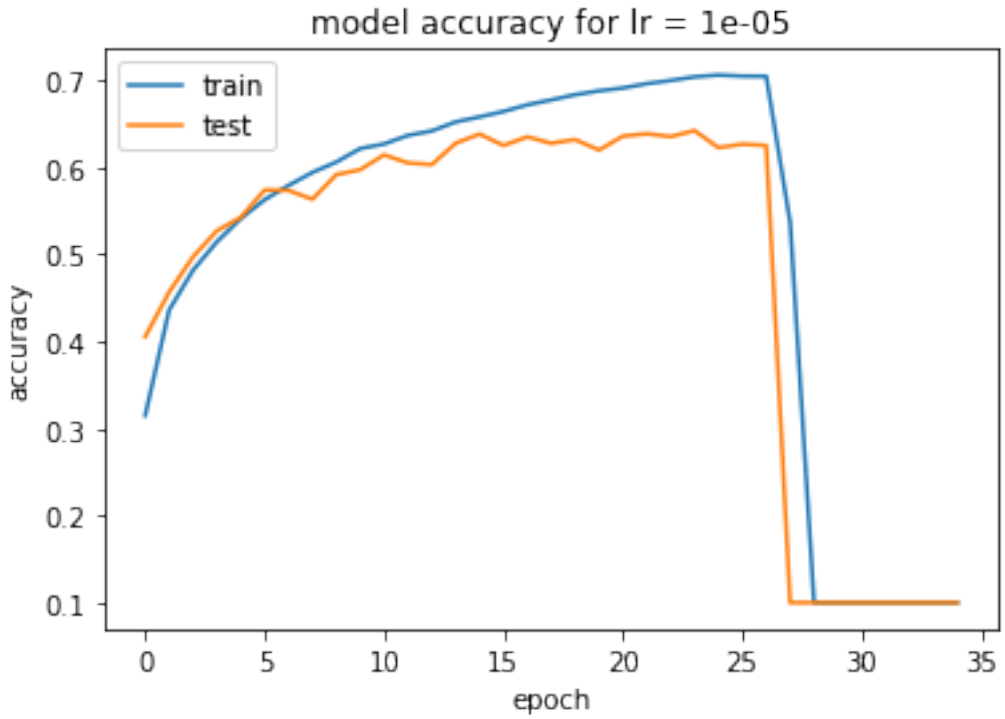
In [14]:

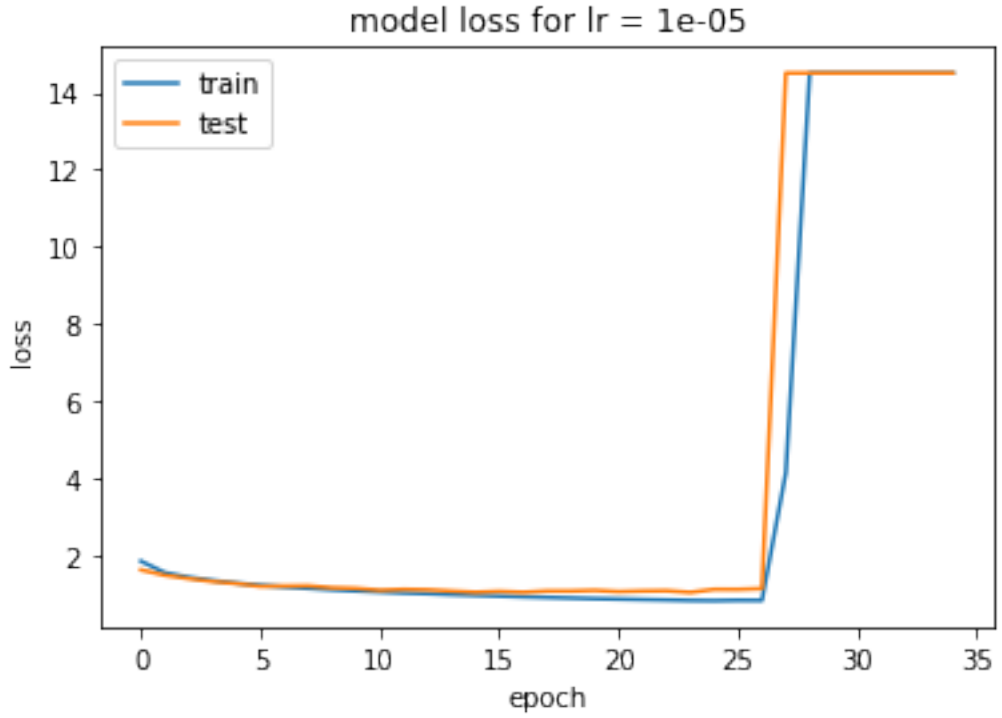
```
Training at Learning Rate = 1e-05
---------------------------------

_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_9 (Conv2D)            (None, 28, 28, 6)         456
_________________________________________________________________
activation_21 (Activation)   (None, 28, 28, 6)         0
_________________________________________________________________
```

```
max_pooling2d_9 (MaxPooling2 (None, 14, 14, 6)         0
_________________________________________________________________
conv2d_10 (Conv2D)           (None, 10, 10, 16)        2416
_________________________________________________________________
activation_22 (Activation)   (None, 10, 10, 16)        0
_________________________________________________________________
max_pooling2d_10 (MaxPooling (None, 5, 5, 16)          0
_________________________________________________________________
flatten_5 (Flatten)          (None, 400)               0
_________________________________________________________________
dense_13 (Dense)             (None, 120)               48120
_________________________________________________________________
activation_23 (Activation)   (None, 120)               0
_________________________________________________________________
dense_14 (Dense)             (None, 84)                10164
_________________________________________________________________
activation_24 (Activation)   (None, 84)                0
_________________________________________________________________
dense_15 (Dense)             (None, 10)                850
_________________________________________________________________
activation_25 (Activation)   (None, 10)                0
=================================================================
Total params: 62,006
Trainable params: 62,006
Non-trainable params: 0
_________________________________________________________________
None
Train on 50000 samples, validate on 10000 samples
Epoch 1/35
50000/50000 [==============================] - 41s 826us/step - loss: 1.8603 - acc: 0.3150 - va
Epoch 2/35
50000/50000 [==============================] - 41s 820us/step - loss: 1.5606 - acc: 0.4359 - va
Epoch 3/35
50000/50000 [==============================] - 42s 831us/step - loss: 1.4420 - acc: 0.4817 - va
Epoch 4/35
50000/50000 [==============================] - 42s 837us/step - loss: 1.3588 - acc: 0.5144 - va
Epoch 5/35
50000/50000 [==============================] - 42s 839us/step - loss: 1.2882 - acc: 0.5411 - va
Epoch 6/35
50000/50000 [==============================] - 42s 842us/step - loss: 1.2349 - acc: 0.5627 - va
Epoch 7/35
50000/50000 [==============================] - 43s 857us/step - loss: 1.1903 - acc: 0.5791 - va
Epoch 8/35
50000/50000 [==============================] - 43s 866us/step - loss: 1.1534 - acc: 0.5941 - va
Epoch 9/35
50000/50000 [==============================] - 44s 875us/step - loss: 1.1174 - acc: 0.6060 - va
Epoch 10/35
50000/50000 [==============================] - 44s 883us/step - loss: 1.0881 - acc: 0.6215 - va
```

```
Epoch 11/35
50000/50000 [==============================] - 44s 890us/step - loss: 1.0616 - acc: 0.6268 - va
Epoch 12/35
50000/50000 [==============================] - 45s 902us/step - loss: 1.0354 - acc: 0.6366 - va
Epoch 13/35
50000/50000 [==============================] - 46s 916us/step - loss: 1.0175 - acc: 0.6418 - va
Epoch 14/35
50000/50000 [==============================] - 46s 930us/step - loss: 0.9938 - acc: 0.6522 - va
Epoch 15/35
50000/50000 [==============================] - 45s 900us/step - loss: 0.9738 - acc: 0.6579 - va
Epoch 16/35
50000/50000 [==============================] - 44s 887us/step - loss: 0.9542 - acc: 0.6641 - va
Epoch 17/35
50000/50000 [==============================] - 45s 896us/step - loss: 0.9353 - acc: 0.6718 - va
Epoch 18/35
50000/50000 [==============================] - 45s 910us/step - loss: 0.9191 - acc: 0.6773 - va
Epoch 19/35
50000/50000 [==============================] - 46s 926us/step - loss: 0.9032 - acc: 0.6833 - va
Epoch 20/35
50000/50000 [==============================] - 46s 927us/step - loss: 0.8869 - acc: 0.6878 - va
Epoch 21/35
50000/50000 [==============================] - 47s 934us/step - loss: 0.8757 - acc: 0.6910 - va
Epoch 22/35
50000/50000 [==============================] - 47s 947us/step - loss: 0.8639 - acc: 0.6960 - va
Epoch 23/35
50000/50000 [==============================] - 48s 956us/step - loss: 0.8535 - acc: 0.6997 - va
Epoch 24/35
50000/50000 [==============================] - 48s 962us/step - loss: 0.8407 - acc: 0.7039 - va
Epoch 25/35
50000/50000 [==============================] - 48s 969us/step - loss: 0.8355 - acc: 0.7059 - va
Epoch 26/35
50000/50000 [==============================] - 49s 972us/step - loss: 0.8444 - acc: 0.7047 - va
Epoch 27/35
50000/50000 [==============================] - 49s 977us/step - loss: 0.8418 - acc: 0.7045 - va
Epoch 28/35
50000/50000 [==============================] - 50s 993us/step - loss: 4.1497 - acc: 0.5367 - va
Epoch 29/35
50000/50000 [==============================] - 50s 1ms/step - loss: 14.5063 - acc: 0.1000 - val
Epoch 30/35
50000/50000 [==============================] - 50s 1ms/step - loss: 14.5063 - acc: 0.1000 - val
Epoch 31/35
50000/50000 [==============================] - 50s 1ms/step - loss: 14.5063 - acc: 0.1000 - val
Epoch 32/35
50000/50000 [==============================] - 50s 998us/step - loss: 14.5063 - acc: 0.1000 - v
Epoch 33/35
50000/50000 [==============================] - 50s 1ms/step - loss: 14.5063 - acc: 0.1000 - val
Epoch 34/35
50000/50000 [==============================] - 50s 1ms/step - loss: 14.5063 - acc: 0.1000 - val
```

```
Epoch 35/35
50000/50000 [==============================] - 51s 1ms/step - loss: 14.5063 - acc: 0.1000 - val
```

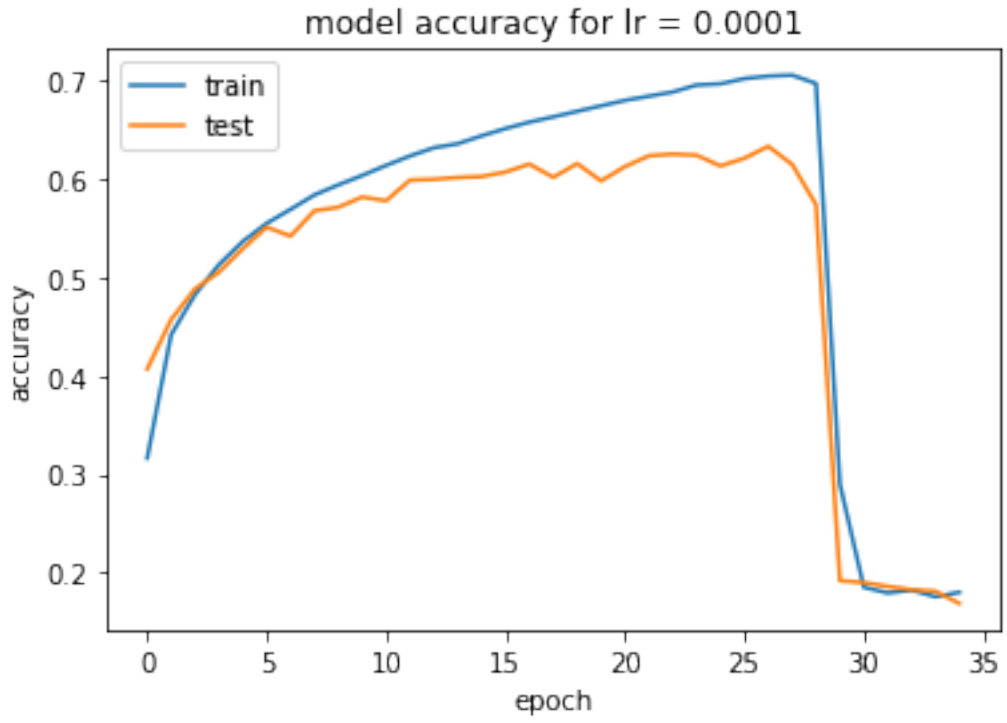


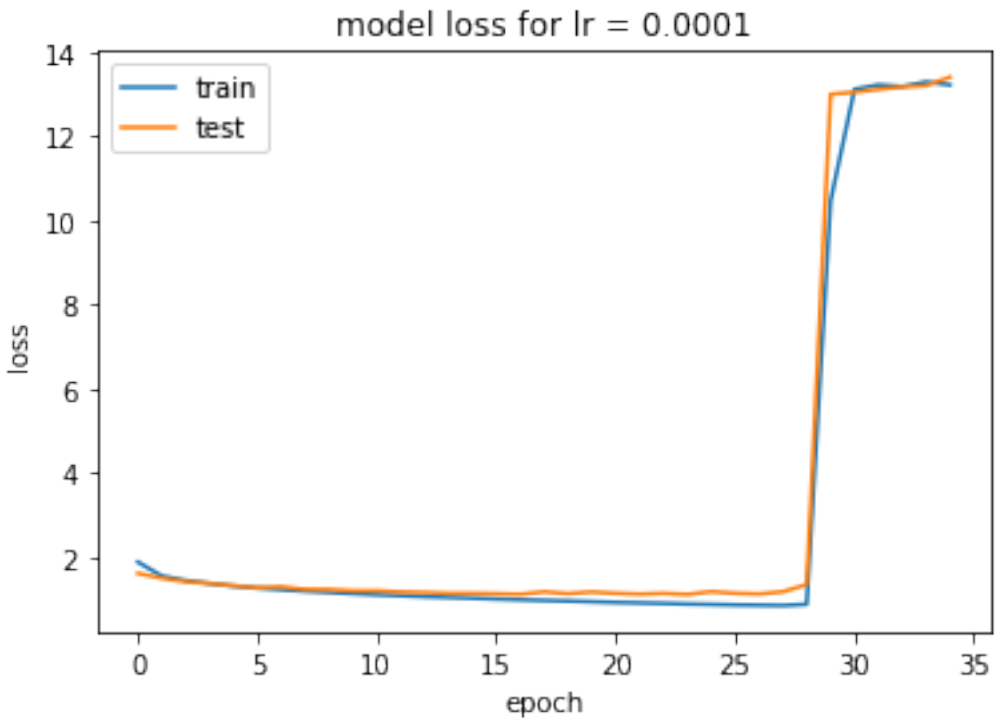


```
Training at Learning Rate = 0.0001
----------------------------------

_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_11 (Conv2D)           (None, 28, 28, 6)         456
_________________________________________________________________
activation_26 (Activation)   (None, 28, 28, 6)         0
_________________________________________________________________
max_pooling2d_11 (MaxPooling (None, 14, 14, 6)         0
_________________________________________________________________
conv2d_12 (Conv2D)           (None, 10, 10, 16)        2416
_________________________________________________________________
activation_27 (Activation)   (None, 10, 10, 16)        0
_________________________________________________________________
max_pooling2d_12 (MaxPooling (None, 5, 5, 16)          0
_________________________________________________________________
flatten_6 (Flatten)          (None, 400)               0
_________________________________________________________________
dense_16 (Dense)             (None, 120)               48120
_________________________________________________________________
activation_28 (Activation)   (None, 120)               0
_________________________________________________________________
dense_17 (Dense)             (None, 84)                10164
_________________________________________________________________
activation_29 (Activation)   (None, 84)                0
_________________________________________________________________
dense_18 (Dense)             (None, 10)                850
_________________________________________________________________
activation_30 (Activation)   (None, 10)                0
=================================================================
Total params: 62,006
Trainable params: 62,006
Non-trainable params: 0
_________________________________________________________________
None
Train on 50000 samples, validate on 10000 samples
Epoch 1/35
50000/50000 [==============================] - 48s 964us/step - loss: 1.8739 - acc: 0.3162 - va
Epoch 2/35
50000/50000 [==============================] - 38s 751us/step - loss: 1.5411 - acc: 0.4415 - va
Epoch 3/35
50000/50000 [==============================] - 38s 764us/step - loss: 1.4341 - acc: 0.4825 - va
Epoch 4/35
50000/50000 [==============================] - 39s 772us/step - loss: 1.3625 - acc: 0.5128 - va
```

```
Epoch 5/35
50000/50000 [==============================] - 39s 777us/step - loss: 1.3020 - acc: 0.5364 - va
Epoch 6/35
50000/50000 [==============================] - 40s 790us/step - loss: 1.2532 - acc: 0.5548 - va
Epoch 7/35
50000/50000 [==============================] - 40s 806us/step - loss: 1.2156 - acc: 0.5691 - va
Epoch 8/35
50000/50000 [==============================] - 41s 830us/step - loss: 1.1804 - acc: 0.5837 - va
Epoch 9/35
50000/50000 [==============================] - 41s 825us/step - loss: 1.1509 - acc: 0.5939 - va
Epoch 10/35
50000/50000 [==============================] - 41s 828us/step - loss: 1.1211 - acc: 0.6035 - va
Epoch 11/35
50000/50000 [==============================] - 42s 837us/step - loss: 1.0957 - acc: 0.6137 - va
Epoch 12/35
50000/50000 [==============================] - 42s 845us/step - loss: 1.0742 - acc: 0.6233 - va
Epoch 13/35
50000/50000 [==============================] - 43s 862us/step - loss: 1.0498 - acc: 0.6317 - va
Epoch 14/35
50000/50000 [==============================] - 43s 869us/step - loss: 1.0321 - acc: 0.6357 - va
Epoch 15/35
50000/50000 [==============================] - 44s 884us/step - loss: 1.0144 - acc: 0.6438 - va
Epoch 16/35
50000/50000 [==============================] - 45s 892us/step - loss: 0.9940 - acc: 0.6512 - va
Epoch 17/35
50000/50000 [==============================] - 45s 901us/step - loss: 0.9760 - acc: 0.6577 - va
Epoch 18/35
50000/50000 [==============================] - 46s 910us/step - loss: 0.9602 - acc: 0.6631 - va
Epoch 19/35
50000/50000 [==============================] - 46s 922us/step - loss: 0.9461 - acc: 0.6687 - va
Epoch 20/35
50000/50000 [==============================] - 47s 931us/step - loss: 0.9295 - acc: 0.6743 - va
Epoch 21/35
50000/50000 [==============================] - 47s 941us/step - loss: 0.9128 - acc: 0.6798 - va
Epoch 22/35
50000/50000 [==============================] - 48s 954us/step - loss: 0.9012 - acc: 0.6841 - va
Epoch 23/35
50000/50000 [==============================] - 48s 955us/step - loss: 0.8898 - acc: 0.6883 - va
Epoch 24/35
50000/50000 [==============================] - 48s 968us/step - loss: 0.8751 - acc: 0.6954 - va
Epoch 25/35
50000/50000 [==============================] - 49s 985us/step - loss: 0.8650 - acc: 0.6966 - va
Epoch 26/35
50000/50000 [==============================] - 50s 990us/step - loss: 0.8537 - acc: 0.7019 - va
Epoch 27/35
50000/50000 [==============================] - 50s 995us/step - loss: 0.8473 - acc: 0.7045 - va
Epoch 28/35
50000/50000 [==============================] - 50s 1ms/step - loss: 0.8399 - acc: 0.7054 - val
```

```
Epoch 29/35
50000/50000 [==============================] - 51s 1ms/step - loss: 0.8678 - acc: 0.6970 - val
Epoch 30/35
50000/50000 [==============================] - 50s 1ms/step - loss: 10.4601 - acc: 0.2898 - val
Epoch 31/35
50000/50000 [==============================] - 51s 1ms/step - loss: 13.1121 - acc: 0.1850 - val
Epoch 32/35
50000/50000 [==============================] - 50s 1ms/step - loss: 13.2172 - acc: 0.1793 - val
Epoch 33/35
50000/50000 [==============================] - 51s 1ms/step - loss: 13.1774 - acc: 0.1821 - val
Epoch 34/35
50000/50000 [==============================] - 50s 1ms/step - loss: 13.2885 - acc: 0.1754 - val
Epoch 35/35
50000/50000 [==============================] - 50s 1ms/step - loss: 13.2175 - acc: 0.1799 - val
```



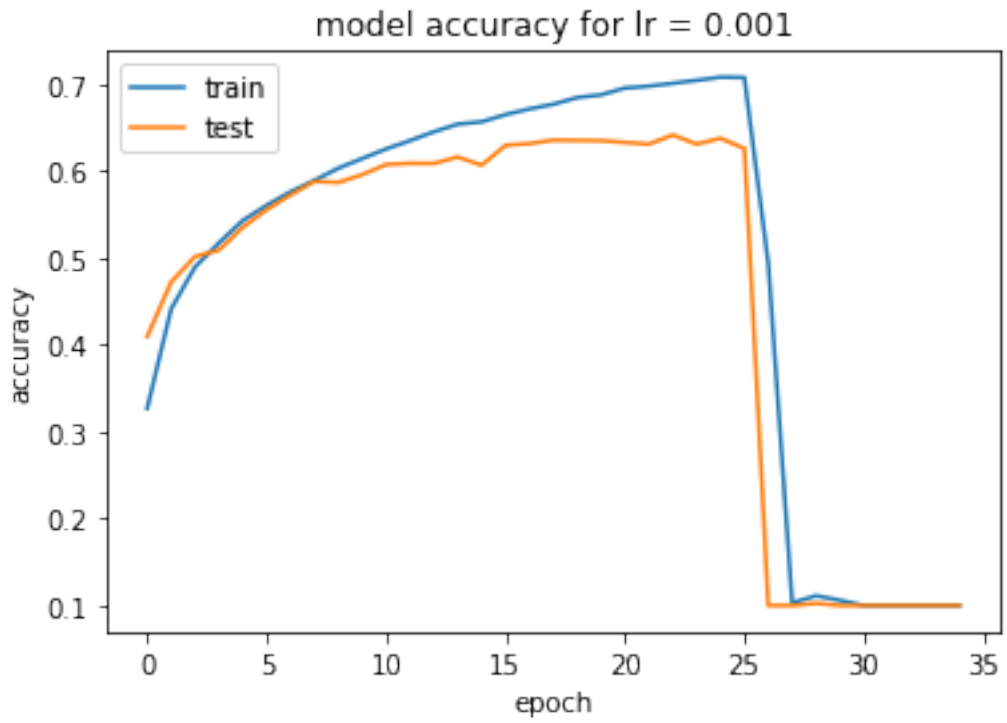


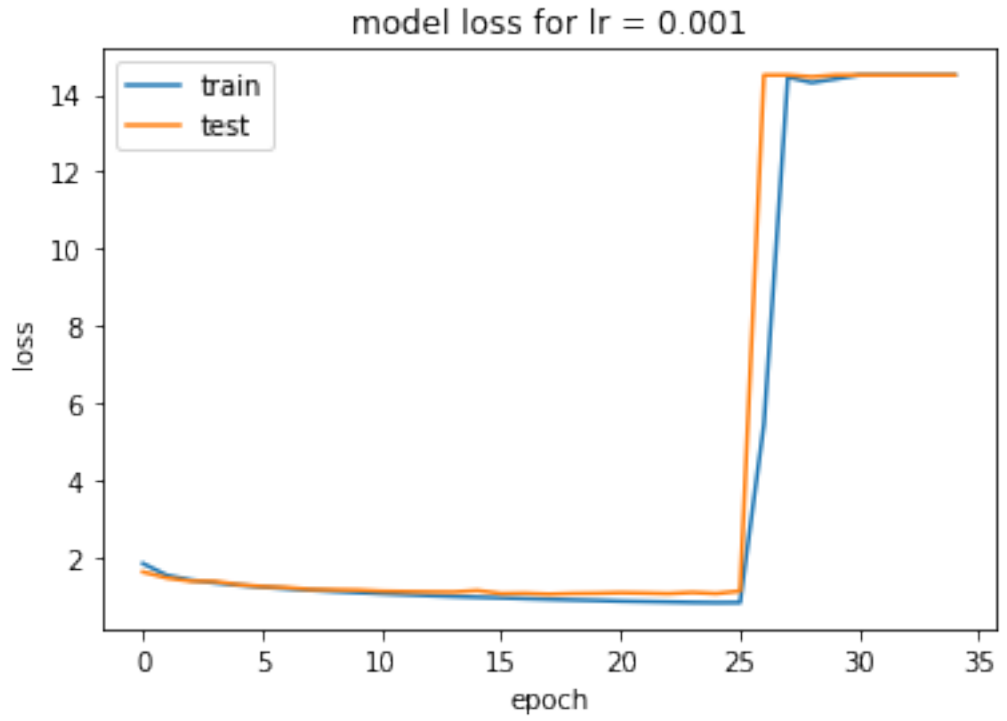

```
Training at Learning Rate = 0.001
----------------------------------
```

Layer (type)	Output Shape	Param #
conv2d_13 (Conv2D)	(None, 28, 28, 6)	456
activation_31 (Activation)	(None, 28, 28, 6)	0
max_pooling2d_13 (MaxPooling	(None, 14, 14, 6)	0
conv2d_14 (Conv2D)	(None, 10, 10, 16)	2416
activation_32 (Activation)	(None, 10, 10, 16)	0
max_pooling2d_14 (MaxPooling	(None, 5, 5, 16)	0
flatten_7 (Flatten)	(None, 400)	0
dense_19 (Dense)	(None, 120)	48120
activation_33 (Activation)	(None, 120)	0
dense_20 (Dense)	(None, 84)	10164

```
_________________________________________________________________
activation_34 (Activation)   (None, 84)                0
_________________________________________________________________
dense_21 (Dense)             (None, 10)                850
_________________________________________________________________
activation_35 (Activation)   (None, 10)                0
=================================================================
Total params: 62,006
Trainable params: 62,006
Non-trainable params: 0
_________________________________________________________________
None
Train on 50000 samples, validate on 10000 samples
Epoch 1/35
50000/50000 [==============================] - 52s 1ms/step - loss: 1.8520 - acc: 0.3267 - val_
Epoch 2/35
50000/50000 [==============================] - 40s 807us/step - loss: 1.5452 - acc: 0.4412 - va
Epoch 3/35
50000/50000 [==============================] - 38s 768us/step - loss: 1.4234 - acc: 0.4896 - va
Epoch 4/35
50000/50000 [==============================] - 39s 775us/step - loss: 1.3506 - acc: 0.5172 - va
Epoch 5/35
50000/50000 [==============================] - 39s 786us/step - loss: 1.2903 - acc: 0.5431 - va
Epoch 6/35
50000/50000 [==============================] - 40s 795us/step - loss: 1.2406 - acc: 0.5606 - va
Epoch 7/35
50000/50000 [==============================] - 41s 812us/step - loss: 1.1974 - acc: 0.5761 - va
Epoch 8/35
50000/50000 [==============================] - 41s 820us/step - loss: 1.1613 - acc: 0.5893 - va
Epoch 9/35
50000/50000 [==============================] - 42s 835us/step - loss: 1.1273 - acc: 0.6033 - va
Epoch 10/35
50000/50000 [==============================] - 42s 831us/step - loss: 1.0981 - acc: 0.6144 - va
Epoch 11/35
50000/50000 [==============================] - 42s 843us/step - loss: 1.0689 - acc: 0.6255 - va
Epoch 12/35
50000/50000 [==============================] - 43s 853us/step - loss: 1.0446 - acc: 0.6350 - va
Epoch 13/35
50000/50000 [==============================] - 43s 868us/step - loss: 1.0196 - acc: 0.6453 - va
Epoch 14/35
50000/50000 [==============================] - 44s 877us/step - loss: 0.9973 - acc: 0.6540 - va
Epoch 15/35
50000/50000 [==============================] - 44s 888us/step - loss: 0.9779 - acc: 0.6567 - va
Epoch 16/35
50000/50000 [==============================] - 45s 899us/step - loss: 0.9601 - acc: 0.6650 - va
Epoch 17/35
50000/50000 [==============================] - 46s 912us/step - loss: 0.9406 - acc: 0.6715 - va
Epoch 18/35
```

```
50000/50000 [==============================] - 46s 924us/step - loss: 0.9228 - acc: 0.6769 - va
Epoch 19/35
50000/50000 [==============================] - 46s 926us/step - loss: 0.9070 - acc: 0.6847 - va
Epoch 20/35
50000/50000 [==============================] - 47s 944us/step - loss: 0.8927 - acc: 0.6878 - va
Epoch 21/35
50000/50000 [==============================] - 47s 949us/step - loss: 0.8751 - acc: 0.6956 - va
Epoch 22/35
50000/50000 [==============================] - 48s 963us/step - loss: 0.8642 - acc: 0.6977 - va
Epoch 23/35
50000/50000 [==============================] - 49s 983us/step - loss: 0.8535 - acc: 0.7011 - va
Epoch 24/35
50000/50000 [==============================] - 49s 986us/step - loss: 0.8427 - acc: 0.7045 - va
Epoch 25/35
50000/50000 [==============================] - 50s 998us/step - loss: 0.8365 - acc: 0.7081 - va
Epoch 26/35
50000/50000 [==============================] - 50s 1ms/step - loss: 0.8385 - acc: 0.7077 - val_
Epoch 27/35
50000/50000 [==============================] - 51s 1ms/step - loss: 5.4573 - acc: 0.4938 - val_
Epoch 28/35
50000/50000 [==============================] - 51s 1ms/step - loss: 14.4534 - acc: 0.1030 - val
Epoch 29/35
50000/50000 [==============================] - 51s 1ms/step - loss: 14.3111 - acc: 0.1112 - val
Epoch 30/35
50000/50000 [==============================] - 51s 1ms/step - loss: 14.4069 - acc: 0.1059 - val
Epoch 31/35
50000/50000 [==============================] - 51s 1ms/step - loss: 14.5063 - acc: 0.1000 - val
Epoch 32/35
50000/50000 [==============================] - 51s 1ms/step - loss: 14.5063 - acc: 0.1000 - val
Epoch 33/35
50000/50000 [==============================] - 51s 1ms/step - loss: 14.5063 - acc: 0.1000 - val
Epoch 34/35
50000/50000 [==============================] - 51s 1ms/step - loss: 14.5063 - acc: 0.1000 - val
Epoch 35/35
50000/50000 [==============================] - 51s 1ms/step - loss: 14.5063 - acc: 0.1000 - val
```

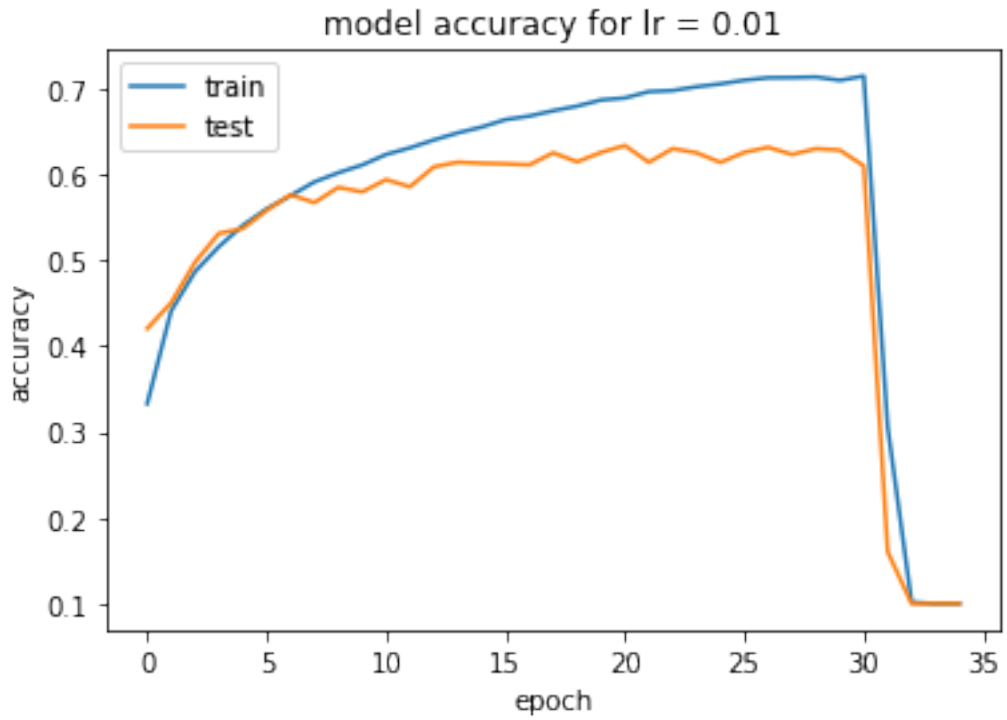

model accuracy for lr = 0.001
train
test
accuracy
epoch
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
5
10
15
20
25
30
35

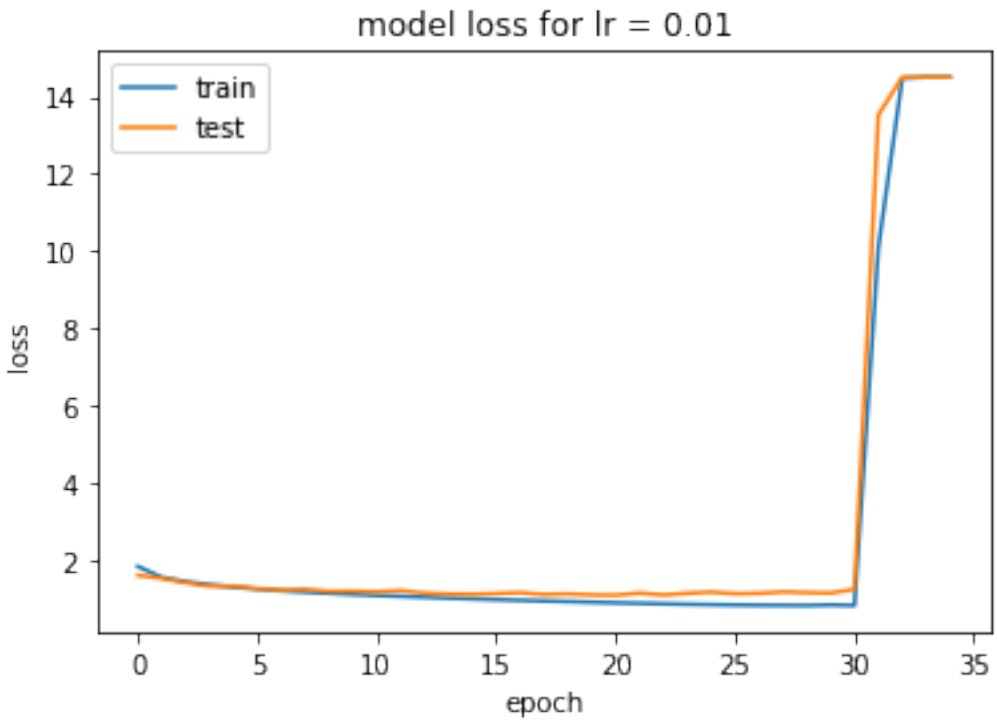

model loss for lr = 0.001
train
test
loss
epoch
14
12
10
8
6
4
2
0
5
10
15
20
25
30
35

```
Training at Learning Rate = 0.01
---------------------------------

_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_15 (Conv2D)           (None, 28, 28, 6)         456
_________________________________________________________________
activation_36 (Activation)   (None, 28, 28, 6)         0
_________________________________________________________________
max_pooling2d_15 (MaxPooling (None, 14, 14, 6)         0
_________________________________________________________________
conv2d_16 (Conv2D)           (None, 10, 10, 16)        2416
_________________________________________________________________
activation_37 (Activation)   (None, 10, 10, 16)        0
_________________________________________________________________
max_pooling2d_16 (MaxPooling (None, 5, 5, 16)          0
_________________________________________________________________
flatten_8 (Flatten)          (None, 400)               0
_________________________________________________________________
dense_22 (Dense)             (None, 120)               48120
_________________________________________________________________
activation_38 (Activation)   (None, 120)               0
_________________________________________________________________
dense_23 (Dense)             (None, 84)                10164
_________________________________________________________________
activation_39 (Activation)   (None, 84)                0
_________________________________________________________________
dense_24 (Dense)             (None, 10)                850
_________________________________________________________________
activation_40 (Activation)   (None, 10)                0
=================================================================
Total params: 62,006
Trainable params: 62,006
Non-trainable params: 0
_________________________________________________________________
None
Train on 50000 samples, validate on 10000 samples
Epoch 1/35
50000/50000 [==============================] - 52s 1ms/step - loss: 1.8252 - acc: 0.3327 - val_
Epoch 2/35
50000/50000 [==============================] - 40s 805us/step - loss: 1.5417 - acc: 0.4407 - va
Epoch 3/35
50000/50000 [==============================] - 39s 771us/step - loss: 1.4302 - acc: 0.4863 - va
Epoch 4/35
50000/50000 [==============================] - 39s 778us/step - loss: 1.3518 - acc: 0.5155 - va
Epoch 5/35
50000/50000 [==============================] - 39s 786us/step - loss: 1.2892 - acc: 0.5402 - va
Epoch 6/35
```

```
50000/50000 [==============================] - 40s 798us/step - loss: 1.2383 - acc: 0.5595 - va
Epoch 7/35
50000/50000 [==============================] - 41s 815us/step - loss: 1.1951 - acc: 0.5749 - va
Epoch 8/35
50000/50000 [==============================] - 41s 824us/step - loss: 1.1605 - acc: 0.5909 - va
Epoch 9/35
50000/50000 [==============================] - 42s 831us/step - loss: 1.1291 - acc: 0.6016 - va
Epoch 10/35
50000/50000 [==============================] - 42s 837us/step - loss: 1.1007 - acc: 0.6106 - va
Epoch 11/35
50000/50000 [==============================] - 42s 843us/step - loss: 1.0727 - acc: 0.6229 - va
Epoch 12/35
50000/50000 [==============================] - 43s 856us/step - loss: 1.0515 - acc: 0.6306 - va
Epoch 13/35
50000/50000 [==============================] - 43s 869us/step - loss: 1.0272 - acc: 0.6398 - va
Epoch 14/35
50000/50000 [==============================] - 44s 879us/step - loss: 1.0035 - acc: 0.6480 - va
Epoch 15/35
50000/50000 [==============================] - 45s 891us/step - loss: 0.9838 - acc: 0.6548 - va
Epoch 16/35
50000/50000 [==============================] - 45s 900us/step - loss: 0.9639 - acc: 0.6634 - va
Epoch 17/35
50000/50000 [==============================] - 46s 927us/step - loss: 0.9463 - acc: 0.6676 - va
Epoch 18/35
50000/50000 [==============================] - 46s 926us/step - loss: 0.9295 - acc: 0.6738 - va
Epoch 19/35
50000/50000 [==============================] - 47s 939us/step - loss: 0.9140 - acc: 0.6791 - va
Epoch 20/35
50000/50000 [==============================] - 47s 950us/step - loss: 0.8974 - acc: 0.6863 - va
Epoch 21/35
50000/50000 [==============================] - 48s 959us/step - loss: 0.8824 - acc: 0.6886 - va
Epoch 22/35
50000/50000 [==============================] - 49s 981us/step - loss: 0.8693 - acc: 0.6960 - va
Epoch 23/35
50000/50000 [==============================] - 50s 997us/step - loss: 0.8562 - acc: 0.6973 - va
Epoch 24/35
50000/50000 [==============================] - 50s 993us/step - loss: 0.8439 - acc: 0.7017 - va
Epoch 25/35
50000/50000 [==============================] - 50s 994us/step - loss: 0.8347 - acc: 0.7050 - va
Epoch 26/35
50000/50000 [==============================] - 50s 1ms/step - loss: 0.8255 - acc: 0.7093 - val_
Epoch 27/35
50000/50000 [==============================] - 51s 1ms/step - loss: 0.8194 - acc: 0.7122 - val_
Epoch 28/35
50000/50000 [==============================] - 51s 1ms/step - loss: 0.8169 - acc: 0.7124 - val_
Epoch 29/35
50000/50000 [==============================] - 51s 1ms/step - loss: 0.8126 - acc: 0.7130 - val_
Epoch 30/35
```

```
50000/50000 [==============================] - 51s 1ms/step - loss: 0.8267 - acc: 0.7092 - val
Epoch 31/35
50000/50000 [==============================] - 51s 1ms/step - loss: 0.8130 - acc: 0.7141 - val
Epoch 32/35
50000/50000 [==============================] - 51s 1ms/step - loss: 10.0942 - acc: 0.3055 - va
Epoch 33/35
50000/50000 [==============================] - 51s 1ms/step - loss: 14.4780 - acc: 0.1017 - va
Epoch 34/35
50000/50000 [==============================] - 51s 1ms/step - loss: 14.5063 - acc: 0.1000 - va
Epoch 35/35
50000/50000 [==============================] - 52s 1ms/step - loss: 14.5063 - acc: 0.1000 - va
```

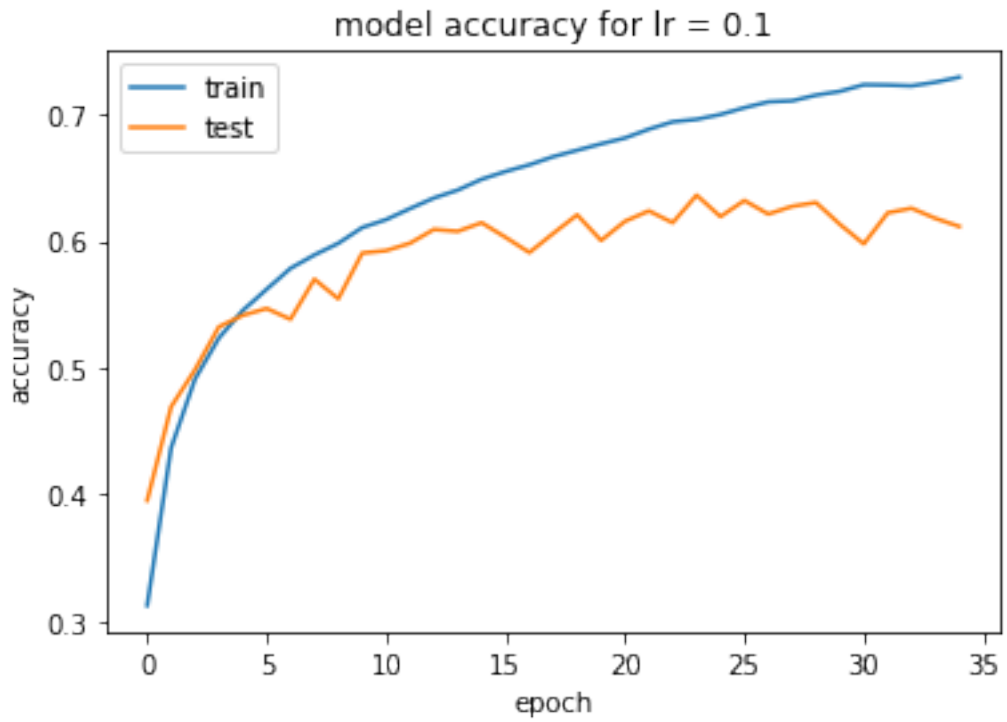


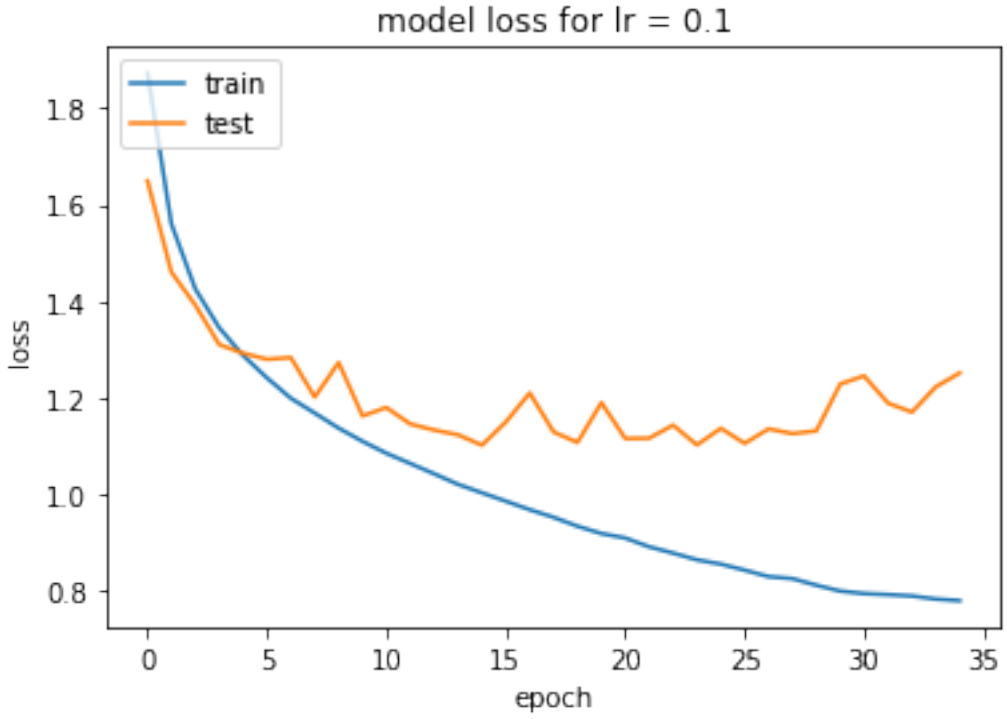



```
Training at Learning Rate = 0.1
---------------------------------

_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_17 (Conv2D)           (None, 28, 28, 6)         456
_________________________________________________________________
activation_41 (Activation)   (None, 28, 28, 6)         0
_________________________________________________________________
max_pooling2d_17 (MaxPooling (None, 14, 14, 6)         0
_________________________________________________________________
conv2d_18 (Conv2D)           (None, 10, 10, 16)        2416
_________________________________________________________________
activation_42 (Activation)   (None, 10, 10, 16)        0
_________________________________________________________________
max_pooling2d_18 (MaxPooling (None, 5, 5, 16)          0
_________________________________________________________________
flatten_9 (Flatten)          (None, 400)               0
_________________________________________________________________
dense_25 (Dense)             (None, 120)               48120
_________________________________________________________________
activation_43 (Activation)   (None, 120)               0
_________________________________________________________________
dense_26 (Dense)             (None, 84)                10164
```

```
_________________________________________________________________
activation_44 (Activation)   (None, 84)                0
_________________________________________________________________
dense_27 (Dense)             (None, 10)                850
_________________________________________________________________
activation_45 (Activation)   (None, 10)                0
=================================================================
Total params: 62,006
Trainable params: 62,006
Non-trainable params: 0
_________________________________________________________________
None
Train on 50000 samples, validate on 10000 samples
Epoch 1/35
50000/50000 [==============================] - 50s 994us/step - loss: 1.8731 - acc: 0.3127 - va
Epoch 2/35
50000/50000 [==============================] - 43s 855us/step - loss: 1.5601 - acc: 0.4369 - va
Epoch 3/35
50000/50000 [==============================] - 37s 740us/step - loss: 1.4257 - acc: 0.4912 - va
Epoch 4/35
50000/50000 [==============================] - 37s 749us/step - loss: 1.3453 - acc: 0.5235 - va
Epoch 5/35
50000/50000 [==============================] - 38s 757us/step - loss: 1.2878 - acc: 0.5452 - va
Epoch 6/35
50000/50000 [==============================] - 38s 769us/step - loss: 1.2414 - acc: 0.5619 - va
Epoch 7/35
50000/50000 [==============================] - 39s 784us/step - loss: 1.1991 - acc: 0.5784 - va
Epoch 8/35
50000/50000 [==============================] - 40s 795us/step - loss: 1.1684 - acc: 0.5890 - va
Epoch 9/35
50000/50000 [==============================] - 40s 801us/step - loss: 1.1372 - acc: 0.5982 - va
Epoch 10/35
50000/50000 [==============================] - 40s 810us/step - loss: 1.1098 - acc: 0.6106 - va
Epoch 11/35
50000/50000 [==============================] - 41s 814us/step - loss: 1.0850 - acc: 0.6168 - va
Epoch 12/35
50000/50000 [==============================] - 41s 822us/step - loss: 1.0639 - acc: 0.6255 - va
Epoch 13/35
50000/50000 [==============================] - 42s 837us/step - loss: 1.0425 - acc: 0.6339 - va
Epoch 14/35
50000/50000 [==============================] - 42s 847us/step - loss: 1.0206 - acc: 0.6401 - va
Epoch 15/35
50000/50000 [==============================] - 43s 855us/step - loss: 1.0032 - acc: 0.6487 - va
Epoch 16/35
50000/50000 [==============================] - 43s 866us/step - loss: 0.9858 - acc: 0.6548 - va
Epoch 17/35
50000/50000 [==============================] - 44s 881us/step - loss: 0.9682 - acc: 0.6600 - va
Epoch 18/35
```

```
50000/50000 [==============================] - 44s 887us/step - loss: 0.9523 - acc: 0.6665 - va
Epoch 19/35
50000/50000 [==============================] - 45s 899us/step - loss: 0.9339 - acc: 0.6715 - va
Epoch 20/35
50000/50000 [==============================] - 45s 910us/step - loss: 0.9187 - acc: 0.6765 - va
Epoch 21/35
50000/50000 [==============================] - 46s 918us/step - loss: 0.9095 - acc: 0.6812 - va
Epoch 22/35
50000/50000 [==============================] - 47s 930us/step - loss: 0.8912 - acc: 0.6881 - va
Epoch 23/35
50000/50000 [==============================] - 47s 939us/step - loss: 0.8783 - acc: 0.6939 - va
Epoch 24/35
50000/50000 [==============================] - 48s 950us/step - loss: 0.8642 - acc: 0.6959 - va
Epoch 25/35
50000/50000 [==============================] - 48s 953us/step - loss: 0.8554 - acc: 0.6997 - va
Epoch 26/35
50000/50000 [==============================] - 48s 965us/step - loss: 0.8428 - acc: 0.7050 - va
Epoch 27/35
50000/50000 [==============================] - 49s 973us/step - loss: 0.8295 - acc: 0.7096 - va
Epoch 28/35
50000/50000 [==============================] - 49s 984us/step - loss: 0.8253 - acc: 0.7105 - va
Epoch 29/35
50000/50000 [==============================] - 49s 979us/step - loss: 0.8115 - acc: 0.7149 - va
Epoch 30/35
50000/50000 [==============================] - 49s 985us/step - loss: 0.7995 - acc: 0.7179 - va
Epoch 31/35
50000/50000 [==============================] - 49s 990us/step - loss: 0.7943 - acc: 0.7232 - va
Epoch 32/35
50000/50000 [==============================] - 49s 982us/step - loss: 0.7921 - acc: 0.7229 - va
Epoch 33/35
50000/50000 [==============================] - 49s 984us/step - loss: 0.7893 - acc: 0.7222 - va
Epoch 34/35
50000/50000 [==============================] - 49s 978us/step - loss: 0.7830 - acc: 0.7251 - va
Epoch 35/35
50000/50000 [==============================] - 49s 981us/step - loss: 0.7796 - acc: 0.7291 - va
```

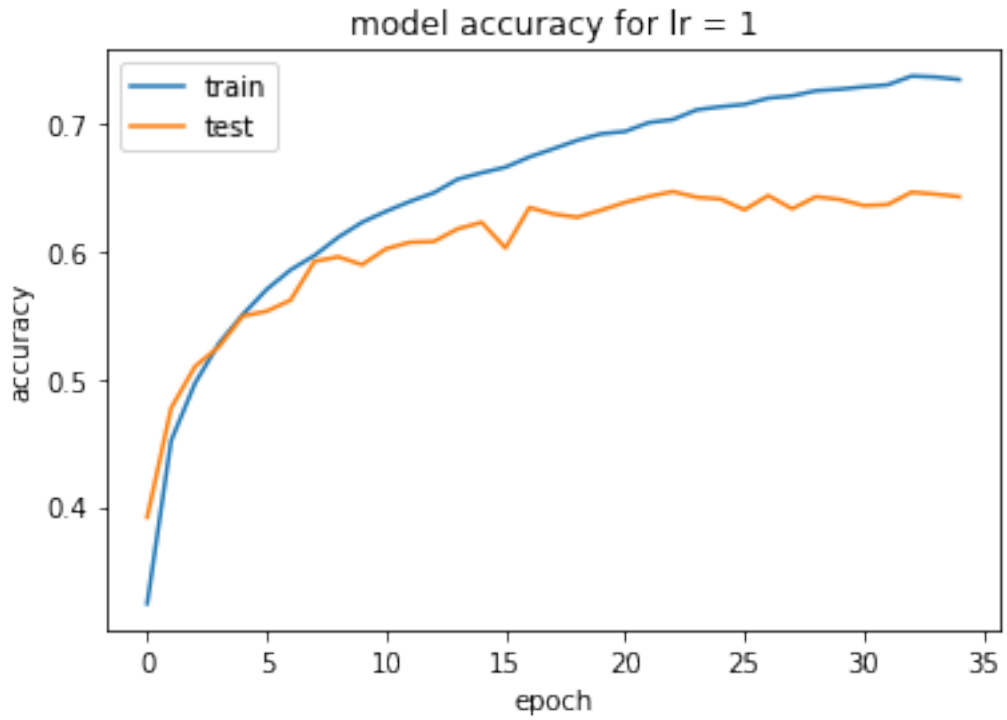

model accuracy for lr = 0.1
train
test
accuracy
epoch
0.3
0.4
0.5
0.6
0.7
0
5
10
15
20
25
30
35

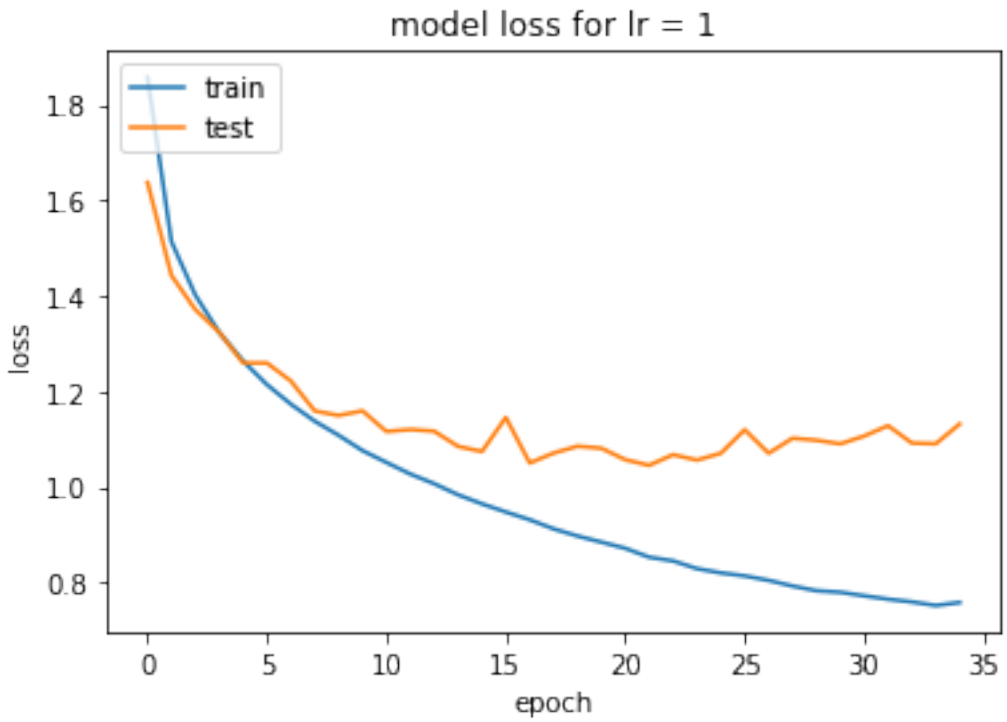

model loss for lr = 0.1
train
test
loss
epoch
0.8
1.0
1.2
1.4
1.6
1.8
0
5
10
15
20
25
30
35

```
Training at Learning Rate = 1
---------------------------------

_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_19 (Conv2D)           (None, 28, 28, 6)         456
_________________________________________________________________
activation_46 (Activation)   (None, 28, 28, 6)         0
_________________________________________________________________
max_pooling2d_19 (MaxPooling (None, 14, 14, 6)         0
_________________________________________________________________
conv2d_20 (Conv2D)           (None, 10, 10, 16)        2416
_________________________________________________________________
activation_47 (Activation)   (None, 10, 10, 16)        0
_________________________________________________________________
max_pooling2d_20 (MaxPooling (None, 5, 5, 16)          0
_________________________________________________________________
flatten_10 (Flatten)         (None, 400)               0
_________________________________________________________________
dense_28 (Dense)             (None, 120)               48120
_________________________________________________________________
activation_48 (Activation)   (None, 120)               0
_________________________________________________________________
dense_29 (Dense)             (None, 84)                10164
_________________________________________________________________
activation_49 (Activation)   (None, 84)                0
_________________________________________________________________
dense_30 (Dense)             (None, 10)                850
_________________________________________________________________
activation_50 (Activation)   (None, 10)                0
=================================================================
Total params: 62,006
Trainable params: 62,006
Non-trainable params: 0
_________________________________________________________________
None
Train on 50000 samples, validate on 10000 samples
Epoch 1/35
50000/50000 [==============================] - 50s 1ms/step - loss: 1.8582 - acc: 0.3240 - val_
Epoch 2/35
50000/50000 [==============================] - 38s 756us/step - loss: 1.5138 - acc: 0.4515 - va
Epoch 3/35
50000/50000 [==============================] - 38s 765us/step - loss: 1.4018 - acc: 0.4966 - va
Epoch 4/35
50000/50000 [==============================] - 39s 773us/step - loss: 1.3235 - acc: 0.5278 - va
Epoch 5/35
50000/50000 [==============================] - 39s 782us/step - loss: 1.2636 - acc: 0.5504 - va
Epoch 6/35
```

```
50000/50000 [==============================] - 40s 791us/step - loss: 1.2141 - acc: 0.5701 - va
Epoch 7/35
50000/50000 [==============================] - 40s 810us/step - loss: 1.1731 - acc: 0.5854 - va
Epoch 8/35
50000/50000 [==============================] - 41s 816us/step - loss: 1.1375 - acc: 0.5967 - va
Epoch 9/35
50000/50000 [==============================] - 41s 824us/step - loss: 1.1079 - acc: 0.6110 - va
Epoch 10/35
50000/50000 [==============================] - 42s 832us/step - loss: 1.0759 - acc: 0.6228 - va
Epoch 11/35
50000/50000 [==============================] - 42s 836us/step - loss: 1.0511 - acc: 0.6313 - va
Epoch 12/35
50000/50000 [==============================] - 43s 852us/step - loss: 1.0267 - acc: 0.6391 - va
Epoch 13/35
50000/50000 [==============================] - 44s 872us/step - loss: 1.0065 - acc: 0.6458 - va
Epoch 14/35
50000/50000 [==============================] - 44s 882us/step - loss: 0.9833 - acc: 0.6565 - va
Epoch 15/35
50000/50000 [==============================] - 45s 894us/step - loss: 0.9643 - acc: 0.6615 - va
Epoch 16/35
50000/50000 [==============================] - 45s 908us/step - loss: 0.9472 - acc: 0.6659 - va
Epoch 17/35
50000/50000 [==============================] - 46s 919us/step - loss: 0.9310 - acc: 0.6739 - va
Epoch 18/35
50000/50000 [==============================] - 47s 943us/step - loss: 0.9119 - acc: 0.6803 - va
Epoch 19/35
50000/50000 [==============================] - 48s 960us/step - loss: 0.8968 - acc: 0.6869 - va
Epoch 20/35
50000/50000 [==============================] - 48s 959us/step - loss: 0.8841 - acc: 0.6920 - va
Epoch 21/35
50000/50000 [==============================] - 49s 973us/step - loss: 0.8712 - acc: 0.6938 - va
Epoch 22/35
50000/50000 [==============================] - 50s 990us/step - loss: 0.8526 - acc: 0.7008 - va
Epoch 23/35
50000/50000 [==============================] - 50s 999us/step - loss: 0.8448 - acc: 0.7032 - va
Epoch 24/35
50000/50000 [==============================] - 50s 999us/step - loss: 0.8286 - acc: 0.7108 - va
Epoch 25/35
50000/50000 [==============================] - 51s 1ms/step - loss: 0.8196 - acc: 0.7133 - val
Epoch 26/35
50000/50000 [==============================] - 52s 1ms/step - loss: 0.8133 - acc: 0.7150 - val
Epoch 27/35
50000/50000 [==============================] - 52s 1ms/step - loss: 0.8040 - acc: 0.7200 - val
Epoch 28/35
50000/50000 [==============================] - 52s 1ms/step - loss: 0.7921 - acc: 0.7218 - val
Epoch 29/35
50000/50000 [==============================] - 52s 1ms/step - loss: 0.7823 - acc: 0.7258 - val
Epoch 30/35
```

```
50000/50000 [==============================] - 52s 1ms/step - loss: 0.7791 - acc: 0.7270 - val
Epoch 31/35
50000/50000 [==============================] - 52s 1ms/step - loss: 0.7716 - acc: 0.7289 - val
Epoch 32/35
50000/50000 [==============================] - 52s 1ms/step - loss: 0.7646 - acc: 0.7304 - val
Epoch 33/35
50000/50000 [==============================] - 52s 1ms/step - loss: 0.7588 - acc: 0.7373 - val
Epoch 34/35
50000/50000 [==============================] - 52s 1ms/step - loss: 0.7514 - acc: 0.7365 - val
Epoch 35/35
50000/50000 [==============================] - 52s 1ms/step - loss: 0.7576 - acc: 0.7345 - val
```





** Q6: [2 points] **

Currently, the **batch-size** is 50. Notice the training loss curve if batch size is changed to 1. Is it smooth or fluctating? Show the effect of batch-size on the learning curves in a plot. Take the values on a log scale. Vary only one parameter at a time.

** A6: **

Observations

1. When the batch-size is 1 then the loss-curve is fluctuating and not stable.
2. As the batch-size increases the training loss curve starts smoothening.

See the graphs below in support of the observations.

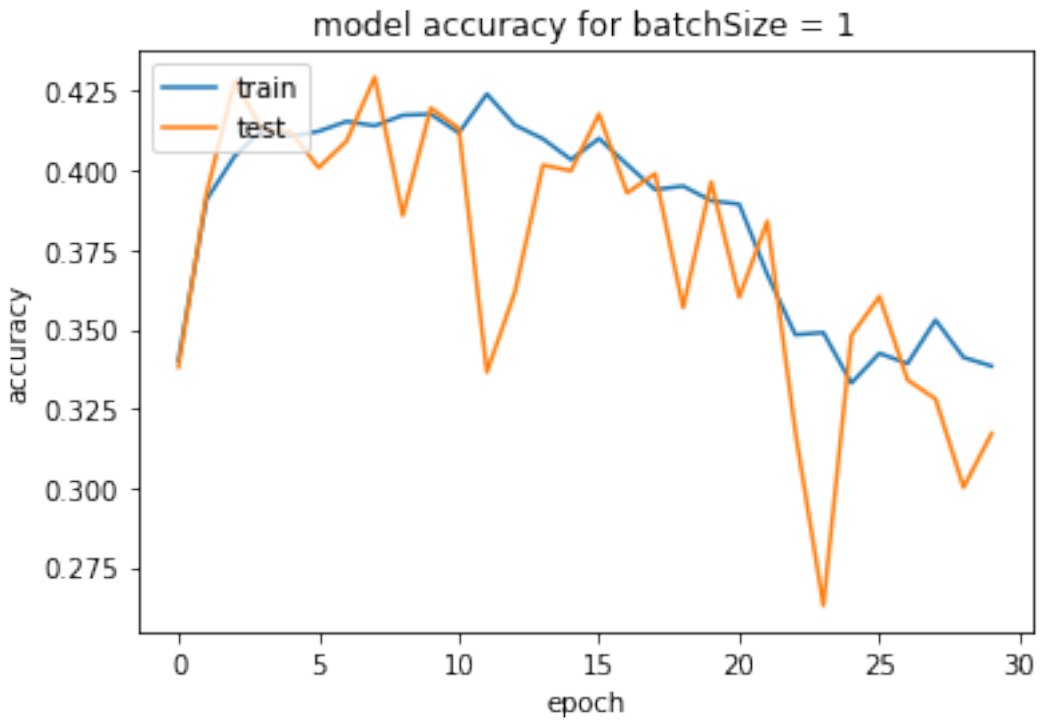
In [ ]:

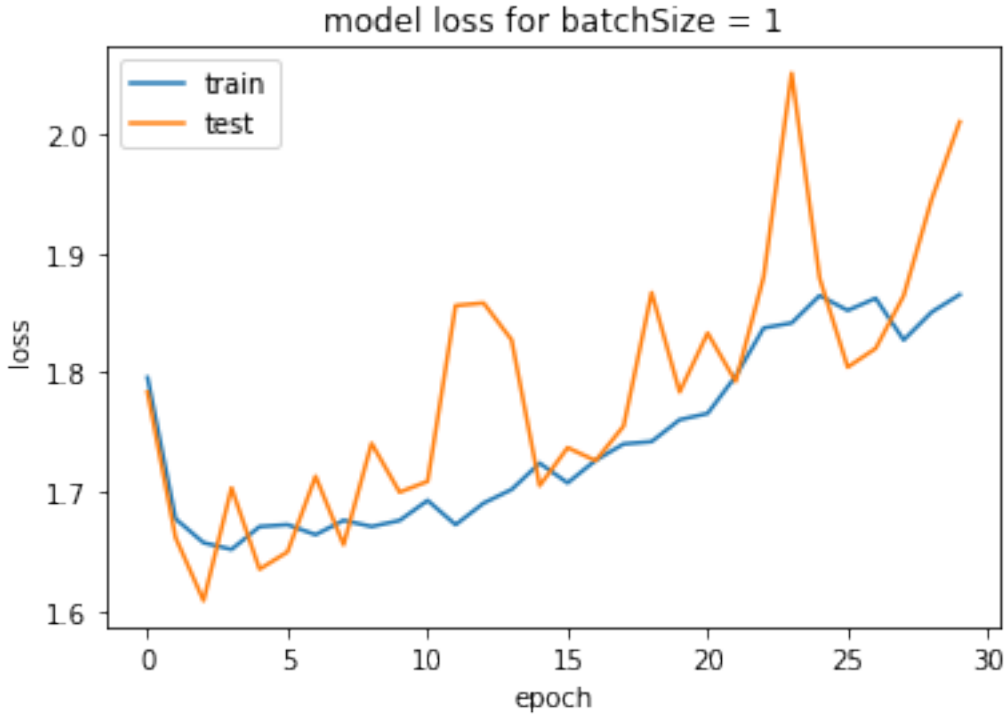
```
Training with Batch Size = 1
----------------------------------
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_1 (Conv2D)            (None, 28, 28, 6)         456
_________________________________________________________________
activation_1 (Activation)    (None, 28, 28, 6)         0
_________________________________________________________________
max_pooling2d_1 (MaxPooling2 (None, 14, 14, 6)         0
_________________________________________________________________
conv2d_2 (Conv2D)            (None, 10, 10, 16)        2416
_________________________________________________________________
```

```
activation_2 (Activation)    (None, 10, 10, 16)        0
_________________________________________________________________
max_pooling2d_2 (MaxPooling2 (None, 5, 5, 16)          0
_________________________________________________________________
flatten_1 (Flatten)          (None, 400)               0
_________________________________________________________________
dense_1 (Dense)              (None, 120)               48120
_________________________________________________________________
activation_3 (Activation)    (None, 120)               0
_________________________________________________________________
dense_2 (Dense)              (None, 84)                10164
_________________________________________________________________
activation_4 (Activation)    (None, 84)                0
_________________________________________________________________
dense_3 (Dense)              (None, 10)                850
_________________________________________________________________
activation_5 (Activation)    (None, 10)                0
=================================================================
Total params: 62,006
Trainable params: 62,006
Non-trainable params: 0
_________________________________________________________________
None
Train on 50000 samples, validate on 10000 samples
Epoch 1/30
50000/50000 [==============================] - 134s 3ms/step - loss: 1.7958 - acc: 0.3402 - val
Epoch 2/30
50000/50000 [==============================] - 134s 3ms/step - loss: 1.6776 - acc: 0.3908 - val
Epoch 3/30
50000/50000 [==============================] - 134s 3ms/step - loss: 1.6576 - acc: 0.4045 - val
Epoch 4/30
50000/50000 [==============================] - 133s 3ms/step - loss: 1.6520 - acc: 0.4129 - val
Epoch 5/30
50000/50000 [==============================] - 133s 3ms/step - loss: 1.6711 - acc: 0.4108 - val
Epoch 6/30
50000/50000 [==============================] - 133s 3ms/step - loss: 1.6727 - acc: 0.4123 - val
Epoch 7/30
50000/50000 [==============================] - 134s 3ms/step - loss: 1.6643 - acc: 0.4155 - val
Epoch 8/30
50000/50000 [==============================] - 133s 3ms/step - loss: 1.6763 - acc: 0.4141 - val
Epoch 9/30
50000/50000 [==============================] - 133s 3ms/step - loss: 1.6711 - acc: 0.4174 - val
Epoch 10/30
50000/50000 [==============================] - 133s 3ms/step - loss: 1.6762 - acc: 0.4178 - val
Epoch 11/30
50000/50000 [==============================] - 133s 3ms/step - loss: 1.6930 - acc: 0.4118 - val
Epoch 12/30
50000/50000 [==============================] - 133s 3ms/step - loss: 1.6727 - acc: 0.4241 - val
```

```
Epoch 13/30
50000/50000 [==============================] - 133s 3ms/step - loss: 1.6908 - acc: 0.4143 - val
Epoch 14/30
50000/50000 [==============================] - 132s 3ms/step - loss: 1.7022 - acc: 0.4100 - val
Epoch 15/30
50000/50000 [==============================] - 133s 3ms/step - loss: 1.7242 - acc: 0.4034 - val
Epoch 16/30
50000/50000 [==============================] - 132s 3ms/step - loss: 1.7077 - acc: 0.4101 - val
Epoch 17/30
50000/50000 [==============================] - 133s 3ms/step - loss: 1.7266 - acc: 0.4019 - val
Epoch 18/30
50000/50000 [==============================] - 133s 3ms/step - loss: 1.7403 - acc: 0.3940 - val
Epoch 19/30
50000/50000 [==============================] - 133s 3ms/step - loss: 1.7422 - acc: 0.3951 - val
Epoch 20/30
50000/50000 [==============================] - 133s 3ms/step - loss: 1.7605 - acc: 0.3905 - val
Epoch 21/30
50000/50000 [==============================] - 133s 3ms/step - loss: 1.7658 - acc: 0.3894 - val
Epoch 22/30
50000/50000 [==============================] - 132s 3ms/step - loss: 1.7969 - acc: 0.3672 - val
Epoch 23/30
50000/50000 [==============================] - 133s 3ms/step - loss: 1.8373 - acc: 0.3482 - val
Epoch 24/30
50000/50000 [==============================] - 133s 3ms/step - loss: 1.8415 - acc: 0.3489 - val
Epoch 25/30
50000/50000 [==============================] - 133s 3ms/step - loss: 1.8644 - acc: 0.3330 - val
Epoch 26/30
50000/50000 [==============================] - 132s 3ms/step - loss: 1.8520 - acc: 0.3424 - val
Epoch 27/30
50000/50000 [==============================] - 133s 3ms/step - loss: 1.8621 - acc: 0.3391 - val
Epoch 28/30
50000/50000 [==============================] - 133s 3ms/step - loss: 1.8272 - acc: 0.3529 - val
Epoch 29/30
50000/50000 [==============================] - 133s 3ms/step - loss: 1.8506 - acc: 0.3411 - val
Epoch 30/30
50000/50000 [==============================] - 133s 3ms/step - loss: 1.8652 - acc: 0.3384 - val
```

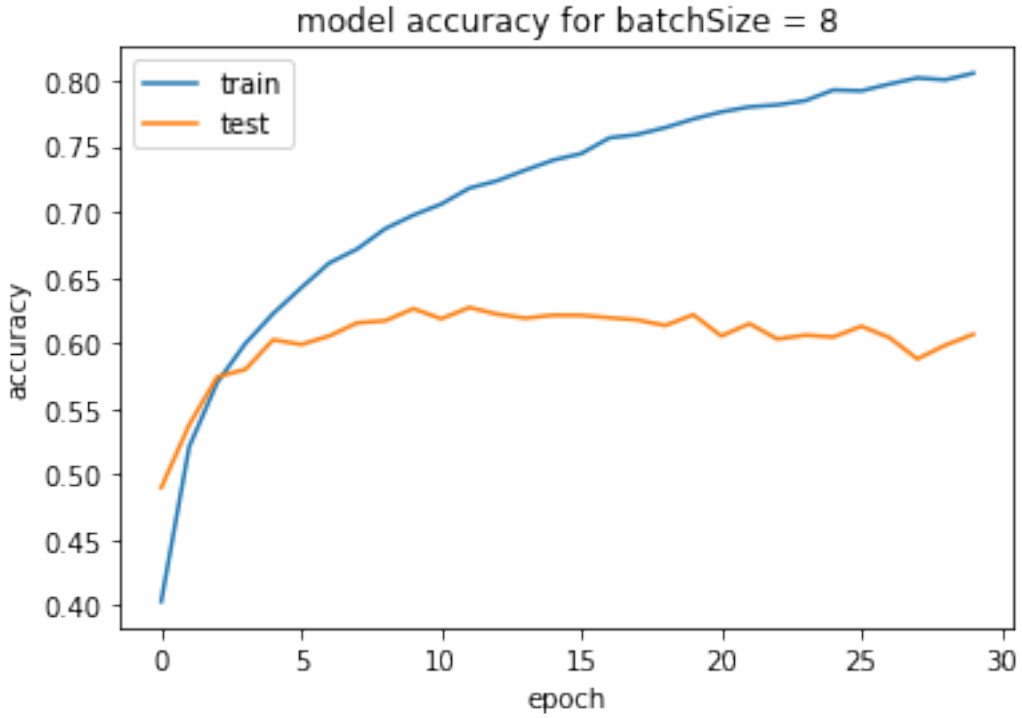

model accuracy for batchSize = 1
train
test
accuracy
epoch
0.425
0.400
0.375
0.350
0.325
0.300
0.275
0
5
10
15
20
25
30

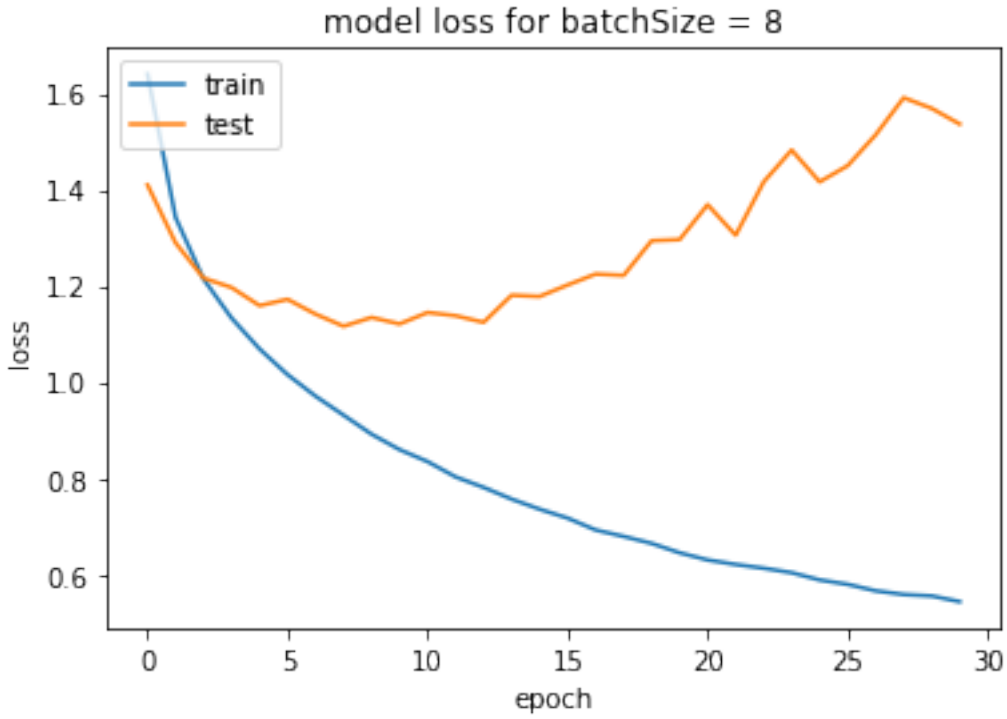

model loss for batchSize = 1
train
test
loss
epoch
2.0
1.9
1.8
1.7
1.6
0
5
10
15
20
25
30

```
Training with Batch Size = 8
---------------------------------

_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_3 (Conv2D)            (None, 28, 28, 6)         456
_________________________________________________________________
activation_6 (Activation)    (None, 28, 28, 6)         0
_________________________________________________________________
max_pooling2d_3 (MaxPooling2 (None, 14, 14, 6)         0
_________________________________________________________________
conv2d_4 (Conv2D)            (None, 10, 10, 16)        2416
_________________________________________________________________
activation_7 (Activation)    (None, 10, 10, 16)        0
_________________________________________________________________
max_pooling2d_4 (MaxPooling2 (None, 5, 5, 16)          0
_________________________________________________________________
flatten_2 (Flatten)          (None, 400)               0
_________________________________________________________________
dense_4 (Dense)              (None, 120)               48120
_________________________________________________________________
activation_8 (Activation)    (None, 120)               0
_________________________________________________________________
dense_5 (Dense)              (None, 84)                10164
_________________________________________________________________
activation_9 (Activation)    (None, 84)                0
_________________________________________________________________
dense_6 (Dense)              (None, 10)                850
_________________________________________________________________
activation_10 (Activation)   (None, 10)                0
=================================================================
Total params: 62,006
Trainable params: 62,006
Non-trainable params: 0
_________________________________________________________________
None
Train on 50000 samples, validate on 10000 samples
Epoch 1/30
50000/50000 [==============================] - 61s 1ms/step - loss: 1.6404 - acc: 0.4031 - val
Epoch 2/30
50000/50000 [==============================] - 61s 1ms/step - loss: 1.3423 - acc: 0.5211 - val
Epoch 3/30
50000/50000 [==============================] - 60s 1ms/step - loss: 1.2141 - acc: 0.5700 - val
Epoch 4/30
50000/50000 [==============================] - 60s 1ms/step - loss: 1.1330 - acc: 0.5996 - val
Epoch 5/30
50000/50000 [==============================] - 60s 1ms/step - loss: 1.0688 - acc: 0.6225 - val
Epoch 6/30
```

```
50000/50000 [==============================] - 61s 1ms/step - loss: 1.0154 - acc: 0.6421 - val
Epoch 7/30
50000/50000 [==============================] - 60s 1ms/step - loss: 0.9706 - acc: 0.6610 - val
Epoch 8/30
50000/50000 [==============================] - 61s 1ms/step - loss: 0.9311 - acc: 0.6717 - val
Epoch 9/30
50000/50000 [==============================] - 60s 1ms/step - loss: 0.8915 - acc: 0.6872 - val
Epoch 10/30
50000/50000 [==============================] - 60s 1ms/step - loss: 0.8595 - acc: 0.6974 - val
Epoch 11/30
50000/50000 [==============================] - 60s 1ms/step - loss: 0.8346 - acc: 0.7059 - val
Epoch 12/30
50000/50000 [==============================] - 60s 1ms/step - loss: 0.8027 - acc: 0.7180 - val
Epoch 13/30
50000/50000 [==============================] - 60s 1ms/step - loss: 0.7810 - acc: 0.7237 - val
Epoch 14/30
50000/50000 [==============================] - 60s 1ms/step - loss: 0.7566 - acc: 0.7318 - val
Epoch 15/30
50000/50000 [==============================] - 60s 1ms/step - loss: 0.7356 - acc: 0.7394 - val
Epoch 16/30
50000/50000 [==============================] - 61s 1ms/step - loss: 0.7171 - acc: 0.7444 - val
Epoch 17/30
50000/50000 [==============================] - 60s 1ms/step - loss: 0.6924 - acc: 0.7563 - val
Epoch 18/30
50000/50000 [==============================] - 60s 1ms/step - loss: 0.6790 - acc: 0.7590 - val
Epoch 19/30
50000/50000 [==============================] - 60s 1ms/step - loss: 0.6645 - acc: 0.7642 - val
Epoch 20/30
50000/50000 [==============================] - 60s 1ms/step - loss: 0.6449 - acc: 0.7707 - val
Epoch 21/30
50000/50000 [==============================] - 60s 1ms/step - loss: 0.6301 - acc: 0.7761 - val
Epoch 22/30
50000/50000 [==============================] - 60s 1ms/step - loss: 0.6206 - acc: 0.7799 - val
Epoch 23/30
50000/50000 [==============================] - 60s 1ms/step - loss: 0.6128 - acc: 0.7815 - val
Epoch 24/30
50000/50000 [==============================] - 60s 1ms/step - loss: 0.6036 - acc: 0.7847 - val
Epoch 25/30
50000/50000 [==============================] - 60s 1ms/step - loss: 0.5885 - acc: 0.7928 - val
Epoch 26/30
50000/50000 [==============================] - 60s 1ms/step - loss: 0.5793 - acc: 0.7922 - val
Epoch 27/30
50000/50000 [==============================] - 60s 1ms/step - loss: 0.5659 - acc: 0.7973 - val
Epoch 28/30
50000/50000 [==============================] - 60s 1ms/step - loss: 0.5582 - acc: 0.8020 - val
Epoch 29/30
50000/50000 [==============================] - 60s 1ms/step - loss: 0.5552 - acc: 0.8006 - val
Epoch 30/30
```

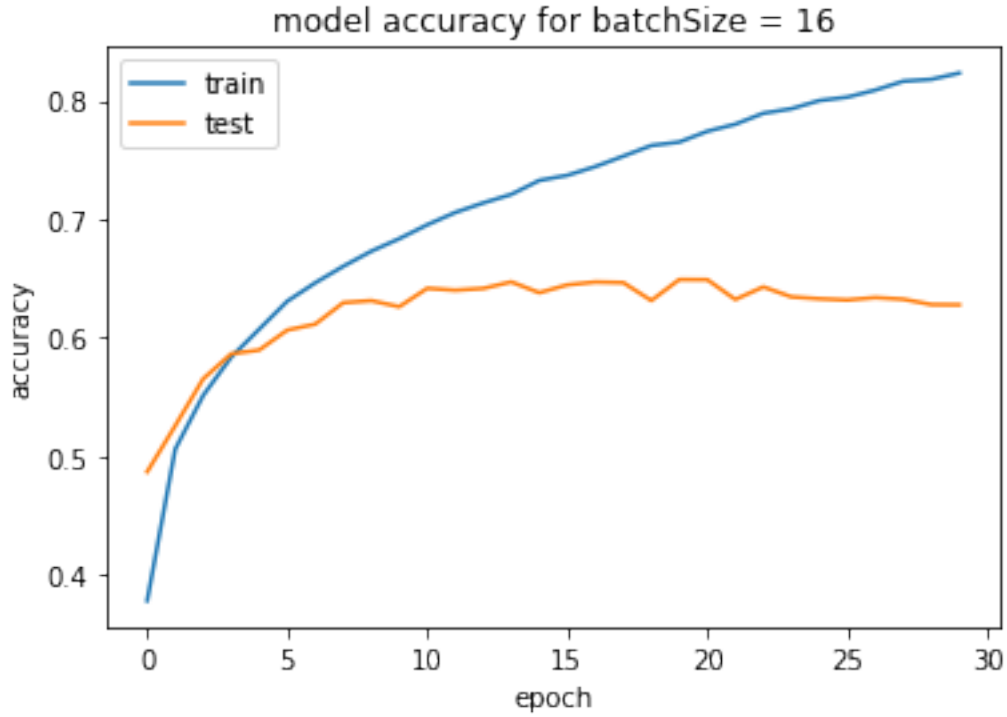
```
50000/50000 [==============================] - 60s 1ms/step - loss: 0.5434 - acc: 0.8056 - val_
```

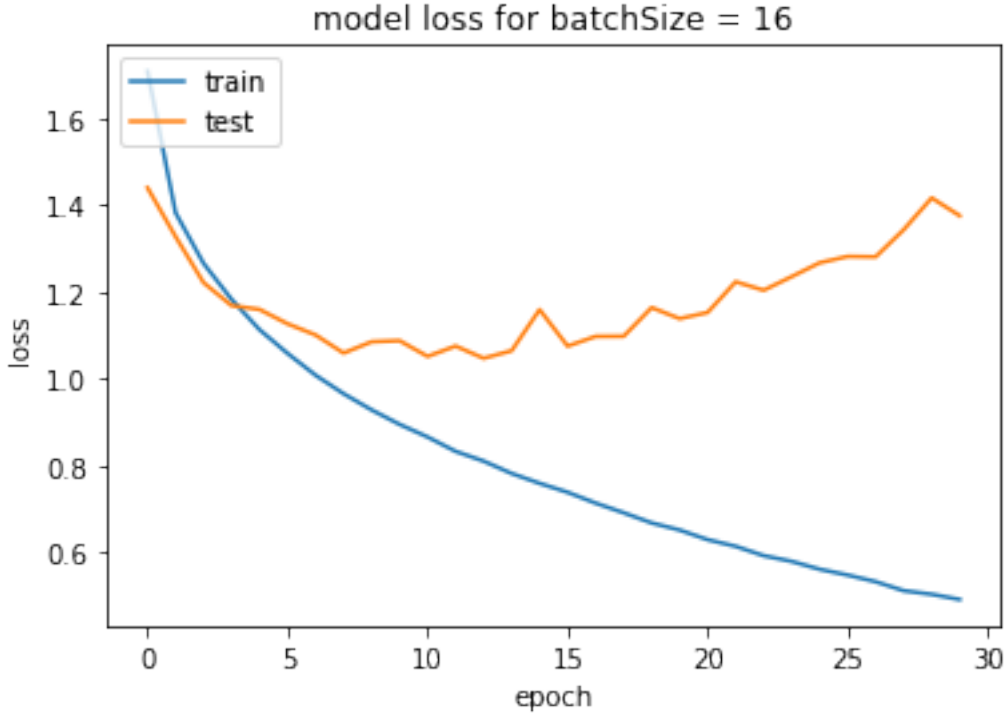




```
Training with Batch Size = 16
---------------------------------

_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_5 (Conv2D)            (None, 28, 28, 6)         456
_________________________________________________________________
activation_11 (Activation)   (None, 28, 28, 6)         0
_________________________________________________________________
max_pooling2d_5 (MaxPooling2 (None, 14, 14, 6)         0
_________________________________________________________________
conv2d_6 (Conv2D)            (None, 10, 10, 16)        2416
_________________________________________________________________
activation_12 (Activation)   (None, 10, 10, 16)        0
_________________________________________________________________
max_pooling2d_6 (MaxPooling2 (None, 5, 5, 16)          0
_________________________________________________________________
flatten_3 (Flatten)          (None, 400)               0
_________________________________________________________________
dense_7 (Dense)              (None, 120)               48120
_________________________________________________________________
activation_13 (Activation)   (None, 120)               0
_________________________________________________________________
dense_8 (Dense)              (None, 84)                10164
_________________________________________________________________
activation_14 (Activation)   (None, 84)                0
_________________________________________________________________
dense_9 (Dense)              (None, 10)                850
_________________________________________________________________
activation_15 (Activation)   (None, 10)                0
=================================================================
Total params: 62,006
Trainable params: 62,006
Non-trainable params: 0
_________________________________________________________________
None
Train on 50000 samples, validate on 10000 samples
Epoch 1/30
50000/50000 [==============================] - 57s 1ms/step - loss: 1.7070 - acc: 0.3786 - val
Epoch 2/30
50000/50000 [==============================] - 57s 1ms/step - loss: 1.3816 - acc: 0.5063 - val
Epoch 3/30
50000/50000 [==============================] - 56s 1ms/step - loss: 1.2652 - acc: 0.5516 - val
Epoch 4/30
50000/50000 [==============================] - 56s 1ms/step - loss: 1.1824 - acc: 0.5839 - val
```

```
Epoch 5/30
50000/50000 [==============================] - 57s 1ms/step - loss: 1.1127 - acc: 0.6074 - val
Epoch 6/30
50000/50000 [==============================] - 56s 1ms/step - loss: 1.0582 - acc: 0.6309 - val
Epoch 7/30
50000/50000 [==============================] - 56s 1ms/step - loss: 1.0080 - acc: 0.6464 - val
Epoch 8/30
50000/50000 [==============================] - 57s 1ms/step - loss: 0.9655 - acc: 0.6603 - val
Epoch 9/30
50000/50000 [==============================] - 56s 1ms/step - loss: 0.8660 - acc: 0.6953 - val
Epoch 12/30
50000/50000 [==============================] - 56s 1ms/step - loss: 0.8330 - acc: 0.7057 - val
Epoch 13/30
50000/50000 [==============================] - 57s 1ms/step - loss: 0.8106 - acc: 0.7138 - val
Epoch 14/30
50000/50000 [==============================] - 56s 1ms/step - loss: 0.7822 - acc: 0.7209 - val
Epoch 15/30
50000/50000 [==============================] - 56s 1ms/step - loss: 0.7595 - acc: 0.7327 - val
Epoch 16/30
50000/50000 [==============================] - 56s 1ms/step - loss: 0.7389 - acc: 0.7370 - val
Epoch 17/30
50000/50000 [==============================] - 56s 1ms/step - loss: 0.7140 - acc: 0.7443 - val
Epoch 18/30
50000/50000 [==============================] - 56s 1ms/step - loss: 0.6918 - acc: 0.7531 - val
Epoch 19/30
50000/50000 [==============================] - 56s 1ms/step - loss: 0.6684 - acc: 0.7621 - val
Epoch 20/30
50000/50000 [==============================] - 56s 1ms/step - loss: 0.6521 - acc: 0.7650 - val
Epoch 21/30
50000/50000 [==============================] - 56s 1ms/step - loss: 0.6299 - acc: 0.7741 - val
Epoch 22/30
50000/50000 [==============================] - 56s 1ms/step - loss: 0.6147 - acc: 0.7801 - val
Epoch 23/30
50000/50000 [==============================] - 56s 1ms/step - loss: 0.5931 - acc: 0.7893 - val
Epoch 24/30
50000/50000 [==============================] - 56s 1ms/step - loss: 0.5800 - acc: 0.7931 - val
Epoch 25/30
50000/50000 [==============================] - 56s 1ms/step - loss: 0.5619 - acc: 0.8000 - val
Epoch 26/30
50000/50000 [==============================] - 56s 1ms/step - loss: 0.5486 - acc: 0.8029 - val
Epoch 27/30
50000/50000 [==============================] - 56s 1ms/step - loss: 0.5333 - acc: 0.8088 - val
Epoch 28/30
50000/50000 [==============================] - 56s 1ms/step - loss: 0.5126 - acc: 0.8163 - val
Epoch 29/30
50000/50000 [==============================] - 56s 1ms/step - loss: 0.5043 - acc: 0.8179 - val
Epoch 30/30
50000/50000 [==============================] - 56s 1ms/step - loss: 0.4924 - acc: 0.8232 - val
```

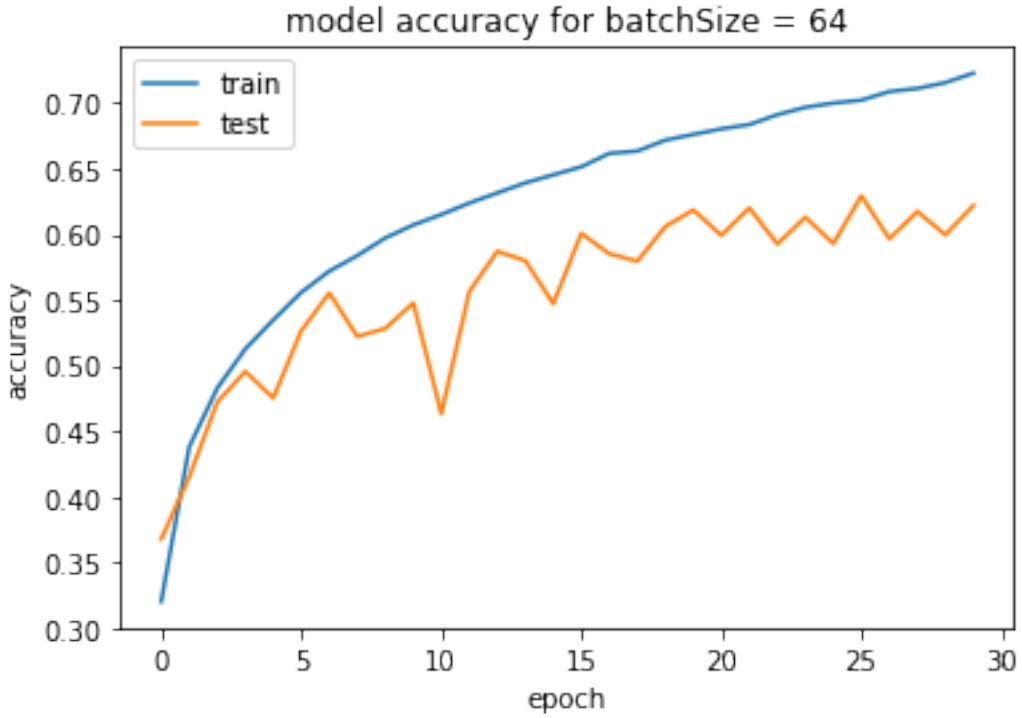

model accuracy for batchSize = 16
train
test
accuracy
epoch
0.4
0.5
0.6
0.7
0.8
0
5
10
15
20
25
30

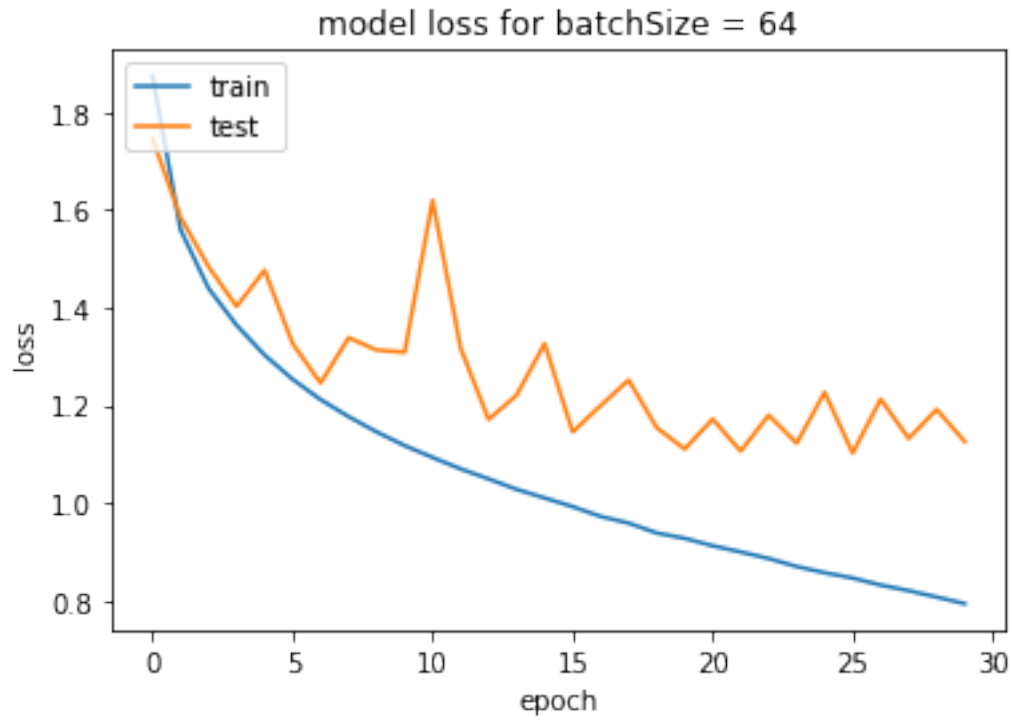

model loss for batchSize = 16
train
test
loss
epoch
0.6
0.8
1.0
1.2
1.4
1.6
0
5
10
15
20
25
30

```
Training with Batch Size = 64
----------------------------------

_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_7 (Conv2D)            (None, 28, 28, 6)         456
_________________________________________________________________
activation_16 (Activation)   (None, 28, 28, 6)         0
_________________________________________________________________
max_pooling2d_7 (MaxPooling2 (None, 14, 14, 6)         0
_________________________________________________________________
conv2d_8 (Conv2D)            (None, 10, 10, 16)        2416
_________________________________________________________________
activation_17 (Activation)   (None, 10, 10, 16)        0
_________________________________________________________________
max_pooling2d_8 (MaxPooling2 (None, 5, 5, 16)          0
_________________________________________________________________
flatten_4 (Flatten)          (None, 400)               0
_________________________________________________________________
dense_10 (Dense)             (None, 120)               48120
_________________________________________________________________
activation_18 (Activation)   (None, 120)               0
_________________________________________________________________
dense_11 (Dense)             (None, 84)                10164
_________________________________________________________________
activation_19 (Activation)   (None, 84)                0
_________________________________________________________________
dense_12 (Dense)             (None, 10)                850
_________________________________________________________________
activation_20 (Activation)   (None, 10)                0
=================================================================
Total params: 62,006
Trainable params: 62,006
Non-trainable params: 0
_________________________________________________________________
None
Train on 50000 samples, validate on 10000 samples
Epoch 1/30
50000/50000 [==============================] - 50s 1ms/step - loss: 1.8737 - acc: 0.3202 - val
Epoch 2/30
50000/50000 [==============================] - 50s 1ms/step - loss: 1.5591 - acc: 0.4381 - val
Epoch 3/30
50000/50000 [==============================] - 50s 1ms/step - loss: 1.4394 - acc: 0.4828 - val
Epoch 4/30
50000/50000 [==============================] - 50s 1ms/step - loss: 1.3640 - acc: 0.5126 - val
Epoch 5/30
50000/50000 [==============================] - 50s 1ms/step - loss: 1.3029 - acc: 0.5348 - val
Epoch 6/30
```

```
50000/50000 [==============================] - 50s 1ms/step - loss: 1.2534 - acc: 0.5558 - val
Epoch 7/30
50000/50000 [==============================] - 50s 1ms/step - loss: 1.2118 - acc: 0.5720 - val
Epoch 8/30
50000/50000 [==============================] - 50s 1ms/step - loss: 1.1768 - acc: 0.5838 - val
Epoch 9/30
50000/50000 [==============================] - 50s 1ms/step - loss: 1.1456 - acc: 0.5973 - val
Epoch 10/30
50000/50000 [==============================] - 50s 1ms/step - loss: 1.1176 - acc: 0.6072 - val
Epoch 11/30
50000/50000 [==============================] - 50s 1ms/step - loss: 1.0933 - acc: 0.6151 - val
Epoch 12/30
50000/50000 [==============================] - 50s 1ms/step - loss: 1.0699 - acc: 0.6239 - val
Epoch 13/30
50000/50000 [==============================] - 50s 1ms/step - loss: 1.0494 - acc: 0.6316 - val
Epoch 14/30
50000/50000 [==============================] - 50s 1ms/step - loss: 1.0280 - acc: 0.6393 - val
Epoch 15/30
50000/50000 [==============================] - 50s 1ms/step - loss: 1.0104 - acc: 0.6454 - val
Epoch 16/30
50000/50000 [==============================] - 50s 1ms/step - loss: 0.9926 - acc: 0.6515 - val
Epoch 17/30
50000/50000 [==============================] - 50s 1ms/step - loss: 0.9726 - acc: 0.6617 - val
Epoch 18/30
50000/50000 [==============================] - 50s 1ms/step - loss: 0.9590 - acc: 0.6635 - val
Epoch 19/30
50000/50000 [==============================] - 50s 1ms/step - loss: 0.9388 - acc: 0.6718 - val
Epoch 20/30
50000/50000 [==============================] - 50s 1ms/step - loss: 0.9278 - acc: 0.6762 - val
Epoch 21/30
50000/50000 [==============================] - 50s 1ms/step - loss: 0.9126 - acc: 0.6804 - val
Epoch 22/30
50000/50000 [==============================] - 50s 1ms/step - loss: 0.8999 - acc: 0.6837 - val
Epoch 23/30
50000/50000 [==============================] - 50s 1ms/step - loss: 0.8865 - acc: 0.6913 - val
Epoch 24/30
50000/50000 [==============================] - 51s 1ms/step - loss: 0.8701 - acc: 0.6969 - val
Epoch 25/30
50000/50000 [==============================] - 50s 1ms/step - loss: 0.8574 - acc: 0.7001 - val
Epoch 26/30
50000/50000 [==============================] - 51s 1ms/step - loss: 0.8465 - acc: 0.7024 - val
Epoch 27/30
50000/50000 [==============================] - 50s 1ms/step - loss: 0.8321 - acc: 0.7089 - val
Epoch 28/30
50000/50000 [==============================] - 50s 1ms/step - loss: 0.8207 - acc: 0.7112 - val
Epoch 29/30
50000/50000 [==============================] - 50s 1ms/step - loss: 0.8076 - acc: 0.7157 - val
Epoch 30/30
```

```
50000/50000 [==============================] - 50s 1ms/step - loss: 0.7942 - acc: 0.7229 - val_
```

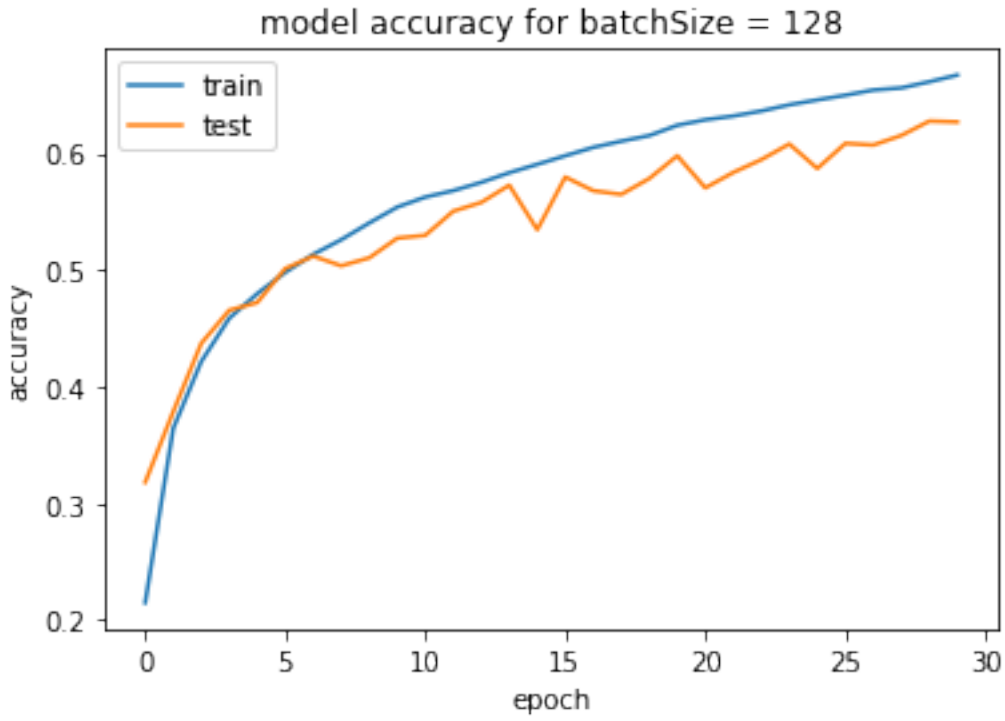


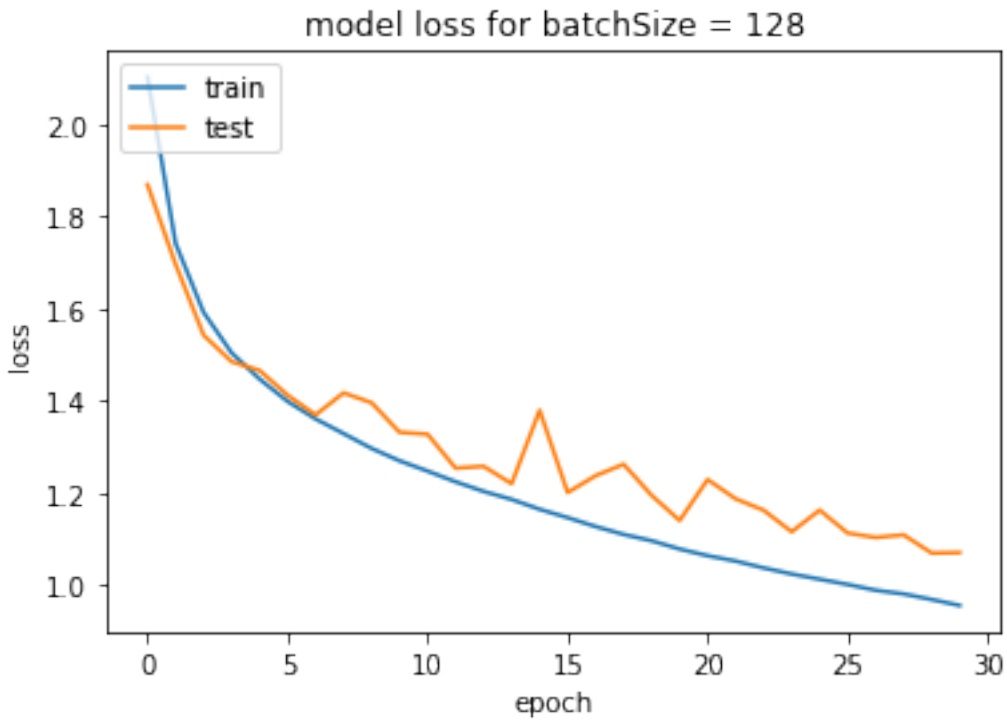


```
Training with Batch Size = 128
----------------------------------

_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_9 (Conv2D)            (None, 28, 28, 6)         456
_________________________________________________________________
activation_21 (Activation)   (None, 28, 28, 6)         0
_________________________________________________________________
max_pooling2d_9 (MaxPooling2 (None, 14, 14, 6)         0
_________________________________________________________________
conv2d_10 (Conv2D)           (None, 10, 10, 16)        2416
_________________________________________________________________
activation_22 (Activation)   (None, 10, 10, 16)        0
_________________________________________________________________
max_pooling2d_10 (MaxPooling (None, 5, 5, 16)          0
_________________________________________________________________
flatten_5 (Flatten)          (None, 400)               0
_________________________________________________________________
dense_13 (Dense)             (None, 120)               48120
_________________________________________________________________
activation_23 (Activation)   (None, 120)               0
_________________________________________________________________
dense_14 (Dense)             (None, 84)                10164
_________________________________________________________________
activation_24 (Activation)   (None, 84)                0
_________________________________________________________________
dense_15 (Dense)             (None, 10)                850
_________________________________________________________________
activation_25 (Activation)   (None, 10)                0
=================================================================
Total params: 62,006
Trainable params: 62,006
Non-trainable params: 0
_________________________________________________________________
None
Train on 50000 samples, validate on 10000 samples
Epoch 1/30
50000/50000 [==============================] - 48s 968us/step - loss: 2.1028 - acc: 0.2148 - va
Epoch 2/30
50000/50000 [==============================] - 48s 966us/step - loss: 1.7425 - acc: 0.3640 - va
Epoch 3/30
50000/50000 [==============================] - 48s 966us/step - loss: 1.5926 - acc: 0.4214 - va
Epoch 4/30
50000/50000 [==============================] - 48s 967us/step - loss: 1.5049 - acc: 0.4585 - va
```

```
Epoch 5/30
50000/50000 [==============================] - 48s 965us/step - loss: 1.4477 - acc: 0.4796 - va
Epoch 6/30
50000/50000 [==============================] - 48s 966us/step - loss: 1.3993 - acc: 0.4979 - va
Epoch 7/30
50000/50000 [==============================] - 48s 967us/step - loss: 1.3613 - acc: 0.5133 - va
Epoch 8/30
50000/50000 [==============================] - 48s 967us/step - loss: 1.3294 - acc: 0.5259 - va
Epoch 9/30
50000/50000 [==============================] - 48s 966us/step - loss: 1.2973 - acc: 0.5402 - va
Epoch 10/30
50000/50000 [==============================] - 48s 965us/step - loss: 1.2703 - acc: 0.5538 - va
Epoch 11/30
50000/50000 [==============================] - 48s 966us/step - loss: 1.2481 - acc: 0.5624 - va
Epoch 12/30
50000/50000 [==============================] - 48s 965us/step - loss: 1.2248 - acc: 0.5679 - va
Epoch 13/30
50000/50000 [==============================] - 48s 966us/step - loss: 1.2040 - acc: 0.5750 - va
Epoch 14/30
50000/50000 [==============================] - 48s 966us/step - loss: 1.1866 - acc: 0.5833 - va
Epoch 15/30
50000/50000 [==============================] - 48s 967us/step - loss: 1.1652 - acc: 0.5905 - va
Epoch 16/30
50000/50000 [==============================] - 48s 965us/step - loss: 1.1471 - acc: 0.5978 - va
Epoch 17/30
50000/50000 [==============================] - 48s 966us/step - loss: 1.1277 - acc: 0.6050 - va
Epoch 18/30
50000/50000 [==============================] - 48s 966us/step - loss: 1.1106 - acc: 0.6103 - va
Epoch 19/30
50000/50000 [==============================] - 48s 966us/step - loss: 1.0969 - acc: 0.6151 - va
Epoch 20/30
50000/50000 [==============================] - 48s 965us/step - loss: 1.0789 - acc: 0.6239 - va
Epoch 21/30
50000/50000 [==============================] - 49s 971us/step - loss: 1.0644 - acc: 0.6287 - va
Epoch 22/30
50000/50000 [==============================] - 48s 967us/step - loss: 1.0528 - acc: 0.6318 - va
Epoch 23/30
50000/50000 [==============================] - 48s 964us/step - loss: 1.0380 - acc: 0.6362 - va
Epoch 24/30
50000/50000 [==============================] - 48s 965us/step - loss: 1.0247 - acc: 0.6415 - va
Epoch 25/30
50000/50000 [==============================] - 48s 966us/step - loss: 1.0134 - acc: 0.6457 - va
Epoch 26/30
50000/50000 [==============================] - 48s 967us/step - loss: 1.0020 - acc: 0.6497 - va
Epoch 27/30
50000/50000 [==============================] - 48s 965us/step - loss: 0.9894 - acc: 0.6541 - va
Epoch 28/30
50000/50000 [==============================] - 48s 966us/step - loss: 0.9815 - acc: 0.6559 - va
```

```
Epoch 29/30
50000/50000 [==============================] - 48s 967us/step - loss: 0.9694 - acc: 0.6612 - va
Epoch 30/30
50000/50000 [==============================] - 48s 968us/step - loss: 0.9564 - acc: 0.6670 - va
```






```
Training with Batch Size = 256
----------------------------------
```

Layer (type)	Output Shape	Param #
conv2d_11 (Conv2D)	(None, 28, 28, 6)	456
activation_26 (Activation)	(None, 28, 28, 6)	0
max_pooling2d_11 (MaxPooling	(None, 14, 14, 6)	0
conv2d_12 (Conv2D)	(None, 10, 10, 16)	2416
activation_27 (Activation)	(None, 10, 10, 16)	0
max_pooling2d_12 (MaxPooling	(None, 5, 5, 16)	0
flatten_6 (Flatten)	(None, 400)	0
dense_16 (Dense)	(None, 120)	48120
activation_28 (Activation)	(None, 120)	0
dense_17 (Dense)	(None, 84)	10164

```
_________________________________________________________________
activation_29 (Activation)   (None, 84)                0
_________________________________________________________________
dense_18 (Dense)             (None, 10)                850
_________________________________________________________________
activation_30 (Activation)   (None, 10)                0
=================================================================
Total params: 62,006
Trainable params: 62,006
Non-trainable params: 0
_________________________________________________________________
None
Train on 50000 samples, validate on 10000 samples
Epoch 1/30
50000/50000 [==============================] - 49s 973us/step - loss: 2.1966 - acc: 0.1856 - va
Epoch 2/30
50000/50000 [==============================] - 48s 970us/step - loss: 1.9138 - acc: 0.3078 - va
Epoch 3/30
50000/50000 [==============================] - 48s 970us/step - loss: 1.7339 - acc: 0.3706 - va
Epoch 4/30
50000/50000 [==============================] - 49s 971us/step - loss: 1.6417 - acc: 0.4034 - va
Epoch 5/30
50000/50000 [==============================] - 49s 971us/step - loss: 1.5837 - acc: 0.4256 - va
Epoch 6/30
50000/50000 [==============================] - 49s 971us/step - loss: 1.5382 - acc: 0.4416 - va
Epoch 7/30
50000/50000 [==============================] - 49s 970us/step - loss: 1.5025 - acc: 0.4561 - va
Epoch 8/30
50000/50000 [==============================] - 48s 970us/step - loss: 1.4690 - acc: 0.4685 - va
Epoch 9/30
50000/50000 [==============================] - 48s 969us/step - loss: 1.4469 - acc: 0.4799 - va
Epoch 10/30
50000/50000 [==============================] - 48s 969us/step - loss: 1.4211 - acc: 0.4886 - va
Epoch 11/30
50000/50000 [==============================] - 49s 971us/step - loss: 1.3994 - acc: 0.4959 - va
Epoch 12/30
50000/50000 [==============================] - 49s 970us/step - loss: 1.3839 - acc: 0.5061 - va
Epoch 13/30
49920/50000 [============================>.] - ETA: 0s - loss: 1.3683 - acc: 0.5105
```

** Q7: [2 points] **

Increase the **number of convolution filters** and experiment. Present your observations using plots and brief explanations. Take the values on a log scale. Vary only one parameter at a time.

** A7: **

Observations

1. Increasing the number of convolution filters in the first layer, improves the accuracy upto a certain number of filters as the model is able to learn more sophesticated and even minute features.
2. However, increasing the no of filters beyond a certain limit results in overfitting and leads to

decrease in accuracy of the model.

Graphs shown below in support of the observations.

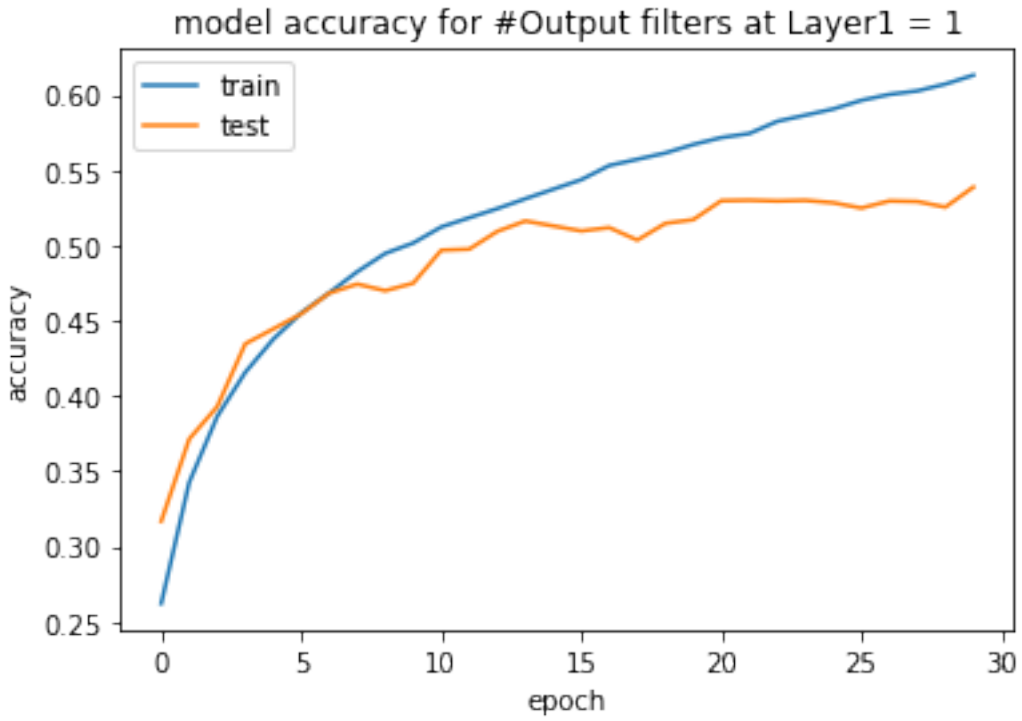
In [9]:

```
Training with #Output filters at Layer1 = 1
-----------------------------------
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_13 (Conv2D)           (None, 28, 28, 1)         76
_________________________________________________________________
activation_31 (Activation)   (None, 28, 28, 1)         0
_________________________________________________________________
max_pooling2d_13 (MaxPooling (None, 14, 14, 1)         0
_________________________________________________________________
conv2d_14 (Conv2D)           (None, 10, 10, 16)        416
_________________________________________________________________
activation_32 (Activation)   (None, 10, 10, 16)        0
_________________________________________________________________
max_pooling2d_14 (MaxPooling (None, 5, 5, 16)          0
_________________________________________________________________
flatten_7 (Flatten)          (None, 400)               0
_________________________________________________________________
dense_19 (Dense)             (None, 120)               48120
_________________________________________________________________
activation_33 (Activation)   (None, 120)               0
_________________________________________________________________
dense_20 (Dense)             (None, 84)                10164
_________________________________________________________________
activation_34 (Activation)   (None, 84)                0
_________________________________________________________________
dense_21 (Dense)             (None, 10)                850
_________________________________________________________________
activation_35 (Activation)   (None, 10)                0
=================================================================
Total params: 59,626
Trainable params: 59,626
Non-trainable params: 0
_________________________________________________________________
None
Train on 50000 samples, validate on 10000 samples
Epoch 1/30
50000/50000 [==============================] - 39s 774us/step - loss: 2.0591 - acc: 0.2621 - va
Epoch 2/30
50000/50000 [==============================] - 39s 773us/step - loss: 1.8256 - acc: 0.3426 - va
Epoch 3/30
50000/50000 [==============================] - 39s 771us/step - loss: 1.6991 - acc: 0.3864 - va
```

```
Epoch 4/30
50000/50000 [==============================] - 38s 769us/step - loss: 1.6240 - acc: 0.4156 - va
Epoch 5/30
50000/50000 [==============================] - 39s 775us/step - loss: 1.5724 - acc: 0.4377 - va
Epoch 6/30
50000/50000 [==============================] - 39s 771us/step - loss: 1.5295 - acc: 0.4551 - va
Epoch 7/30
50000/50000 [==============================] - 39s 771us/step - loss: 1.4931 - acc: 0.4685 - va
Epoch 8/30
50000/50000 [==============================] - 39s 775us/step - loss: 1.4651 - acc: 0.4825 - va
Epoch 9/30
50000/50000 [==============================] - 39s 771us/step - loss: 1.4336 - acc: 0.4947 - va
Epoch 10/30
50000/50000 [==============================] - 39s 771us/step - loss: 1.4079 - acc: 0.5016 - va
Epoch 11/30
50000/50000 [==============================] - 39s 771us/step - loss: 1.3865 - acc: 0.5122 - va
Epoch 12/30
50000/50000 [==============================] - 39s 772us/step - loss: 1.3643 - acc: 0.5184 - va
Epoch 13/30
50000/50000 [==============================] - 39s 771us/step - loss: 1.3476 - acc: 0.5244 - va
Epoch 14/30
50000/50000 [==============================] - 39s 771us/step - loss: 1.3290 - acc: 0.5310 - va
Epoch 15/30
50000/50000 [==============================] - 39s 774us/step - loss: 1.3120 - acc: 0.5373 - va
Epoch 16/30
50000/50000 [==============================] - 39s 771us/step - loss: 1.2973 - acc: 0.5437 - va
Epoch 17/30
50000/50000 [==============================] - 38s 769us/step - loss: 1.2788 - acc: 0.5531 - va
Epoch 18/30
50000/50000 [==============================] - 39s 773us/step - loss: 1.2645 - acc: 0.5572 - va
Epoch 19/30
50000/50000 [==============================] - 38s 769us/step - loss: 1.2500 - acc: 0.5614 - va
Epoch 20/30
50000/50000 [==============================] - 38s 769us/step - loss: 1.2366 - acc: 0.5670 - va
Epoch 21/30
50000/50000 [==============================] - 39s 772us/step - loss: 1.2228 - acc: 0.5716 - va
Epoch 22/30
50000/50000 [==============================] - 38s 768us/step - loss: 1.2079 - acc: 0.5743 - va
Epoch 23/30
50000/50000 [==============================] - 38s 768us/step - loss: 1.1960 - acc: 0.5824 - va
Epoch 24/30
50000/50000 [==============================] - 39s 774us/step - loss: 1.1817 - acc: 0.5865 - va
Epoch 25/30
50000/50000 [==============================] - 39s 771us/step - loss: 1.1705 - acc: 0.5906 - va
Epoch 26/30
50000/50000 [==============================] - 38s 766us/step - loss: 1.1563 - acc: 0.5963 - va
Epoch 27/30
50000/50000 [==============================] - 38s 769us/step - loss: 1.1449 - acc: 0.6003 - va
```

```
Epoch 28/30
50000/50000 [==============================] - 38s 769us/step - loss: 1.1327 - acc: 0.6026 - va
Epoch 29/30
50000/50000 [==============================] - 38s 764us/step - loss: 1.1221 - acc: 0.6071 - va
Epoch 30/30
50000/50000 [==============================] - 38s 766us/step - loss: 1.1103 - acc: 0.6131 - va
```

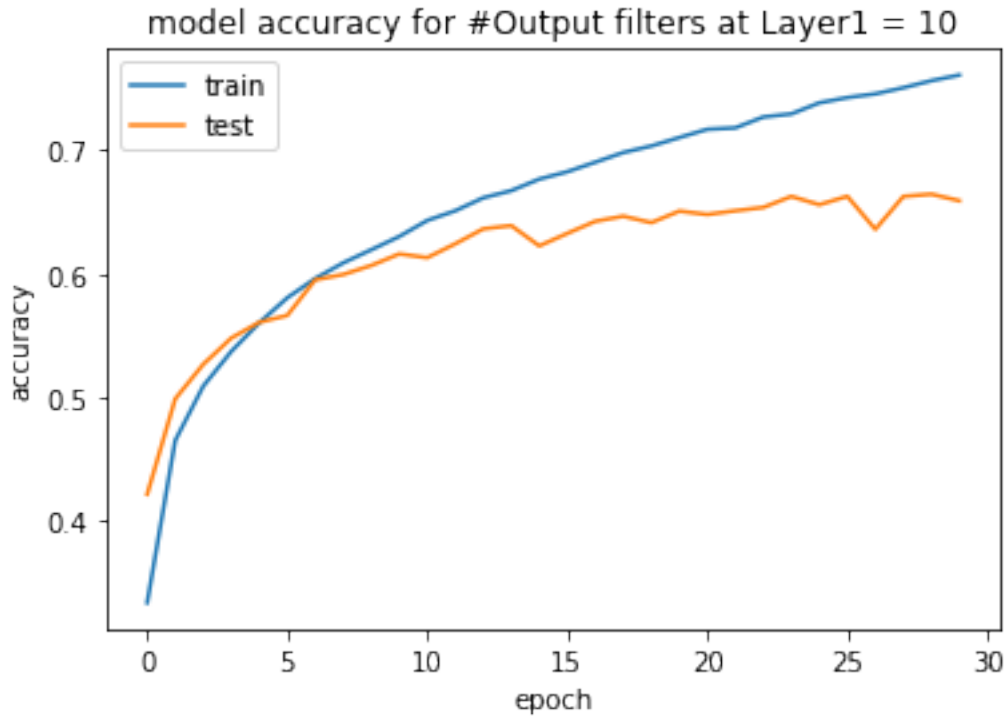



```
Training with #Output filters at Layer1 = 10
-----------------------------------
```

Layer (type)	Output Shape	Param #
conv2d_15 (Conv2D)	(None, 28, 28, 10)	760
activation_36 (Activation)	(None, 28, 28, 10)	0
max_pooling2d_15 (MaxPooling	(None, 14, 14, 10)	0
conv2d_16 (Conv2D)	(None, 10, 10, 16)	4016
activation_37 (Activation)	(None, 10, 10, 16)	0
max_pooling2d_16 (MaxPooling	(None, 5, 5, 16)	0
flatten_8 (Flatten)	(None, 400)	0
dense_22 (Dense)	(None, 120)	48120
activation_38 (Activation)	(None, 120)	0
dense_23 (Dense)	(None, 84)	10164

```
_________________________________________________________________
activation_39 (Activation)   (None, 84)                0
_________________________________________________________________
dense_24 (Dense)             (None, 10)                850
_________________________________________________________________
activation_40 (Activation)   (None, 10)                0
=================================================================
Total params: 63,910
Trainable params: 63,910
Non-trainable params: 0
_________________________________________________________________
None
Train on 50000 samples, validate on 10000 samples
Epoch 1/30
50000/50000 [==============================] - 60s 1ms/step - loss: 1.8218 - acc: 0.3343 - val
Epoch 2/30
50000/50000 [==============================] - 60s 1ms/step - loss: 1.4842 - acc: 0.4653 - val
Epoch 3/30
50000/50000 [==============================] - 60s 1ms/step - loss: 1.3666 - acc: 0.5092 - val
Epoch 4/30
50000/50000 [==============================] - 60s 1ms/step - loss: 1.2887 - acc: 0.5373 - val
Epoch 5/30
50000/50000 [==============================] - 60s 1ms/step - loss: 1.2313 - acc: 0.5604 - val
Epoch 6/30
50000/50000 [==============================] - 60s 1ms/step - loss: 1.1827 - acc: 0.5807 - val
Epoch 7/30
50000/50000 [==============================] - 60s 1ms/step - loss: 1.1405 - acc: 0.5962 - val
Epoch 8/30
50000/50000 [==============================] - 60s 1ms/step - loss: 1.1049 - acc: 0.6089 - val
Epoch 9/30
50000/50000 [==============================] - 60s 1ms/step - loss: 1.0741 - acc: 0.6195 - val
Epoch 10/30
50000/50000 [==============================] - 60s 1ms/step - loss: 1.0438 - acc: 0.6302 - val
Epoch 11/30
50000/50000 [==============================] - 60s 1ms/step - loss: 1.0128 - acc: 0.6432 - val
Epoch 12/30
50000/50000 [==============================] - 60s 1ms/step - loss: 0.9916 - acc: 0.6510 - val
Epoch 13/30
50000/50000 [==============================] - 60s 1ms/step - loss: 0.9638 - acc: 0.6615 - val
Epoch 14/30
50000/50000 [==============================] - 60s 1ms/step - loss: 0.9437 - acc: 0.6672 - val
Epoch 15/30
50000/50000 [==============================] - 60s 1ms/step - loss: 0.9197 - acc: 0.6766 - val
Epoch 16/30
50000/50000 [==============================] - 60s 1ms/step - loss: 0.9033 - acc: 0.6825 - val
Epoch 17/30
50000/50000 [==============================] - 60s 1ms/step - loss: 0.8810 - acc: 0.6902 - val
Epoch 18/30
```

```
50000/50000 [==============================] - 60s 1ms/step - loss: 0.8615 - acc: 0.6981 - val
Epoch 19/30
50000/50000 [==============================] - 60s 1ms/step - loss: 0.8448 - acc: 0.7033 - val
Epoch 20/30
50000/50000 [==============================] - 60s 1ms/step - loss: 0.8287 - acc: 0.7102 - val
Epoch 21/30
50000/50000 [==============================] - 60s 1ms/step - loss: 0.8076 - acc: 0.7168 - val
Epoch 22/30
50000/50000 [==============================] - 60s 1ms/step - loss: 0.7974 - acc: 0.7180 - val
Epoch 23/30
50000/50000 [==============================] - 60s 1ms/step - loss: 0.7773 - acc: 0.7268 - val
Epoch 24/30
50000/50000 [==============================] - 60s 1ms/step - loss: 0.7676 - acc: 0.7293 - val
Epoch 25/30
50000/50000 [==============================] - 60s 1ms/step - loss: 0.7478 - acc: 0.7382 - val
Epoch 26/30
50000/50000 [==============================] - 60s 1ms/step - loss: 0.7370 - acc: 0.7425 - val
Epoch 27/30
50000/50000 [==============================] - 60s 1ms/step - loss: 0.7202 - acc: 0.7455 - val
Epoch 28/30
50000/50000 [==============================] - 60s 1ms/step - loss: 0.7074 - acc: 0.7504 - val
Epoch 29/30
50000/50000 [==============================] - 60s 1ms/step - loss: 0.6933 - acc: 0.7561 - val
Epoch 30/30
50000/50000 [==============================] - 60s 1ms/step - loss: 0.6816 - acc: 0.7607 - val
```

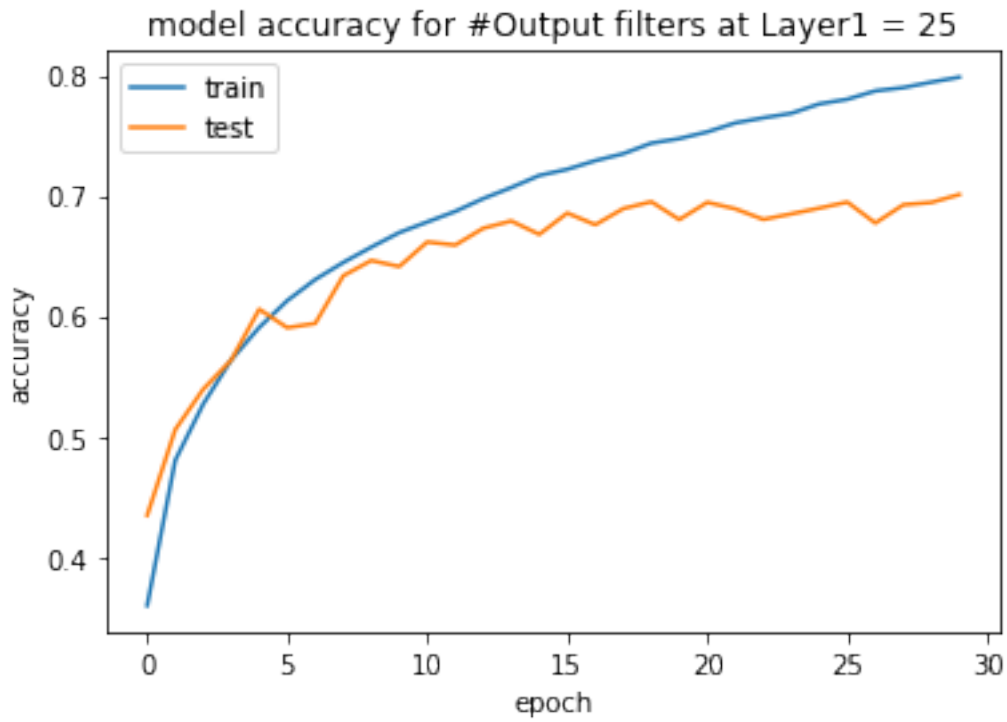



```
Training with #Output filters at Layer1 = 25
-----------------------------------
```

Layer (type)	Output Shape	Param #
conv2d_17 (Conv2D)	(None, 28, 28, 25)	1900
activation_41 (Activation)	(None, 28, 28, 25)	0
max_pooling2d_17 (MaxPooling	(None, 14, 14, 25)	0
conv2d_18 (Conv2D)	(None, 10, 10, 16)	10016
activation_42 (Activation)	(None, 10, 10, 16)	0
max_pooling2d_18 (MaxPooling	(None, 5, 5, 16)	0
flatten_9 (Flatten)	(None, 400)	0
dense_25 (Dense)	(None, 120)	48120

```
activation_43 (Activation)   (None, 120)              0
_________________________________________________________________
dense_26 (Dense)             (None, 84)                10164
_________________________________________________________________
activation_44 (Activation)   (None, 84)                0
_________________________________________________________________
dense_27 (Dense)             (None, 10)                850
_________________________________________________________________
activation_45 (Activation)   (None, 10)                0
=================================================================
Total params: 71,050
Trainable params: 71,050
Non-trainable params: 0
_________________________________________________________________
None
Train on 50000 samples, validate on 10000 samples
Epoch 1/30
50000/50000 [==============================] - 93s 2ms/step - loss: 1.7594 - acc: 0.3597 - val
Epoch 2/30
50000/50000 [==============================] - 93s 2ms/step - loss: 1.4482 - acc: 0.4802 - val
Epoch 3/30
50000/50000 [==============================] - 92s 2ms/step - loss: 1.3272 - acc: 0.5270 - val
Epoch 4/30
50000/50000 [==============================] - 92s 2ms/step - loss: 1.2308 - acc: 0.5637 - val
Epoch 5/30
50000/50000 [==============================] - 92s 2ms/step - loss: 1.1603 - acc: 0.5907 - val
Epoch 6/30
50000/50000 [==============================] - 92s 2ms/step - loss: 1.1028 - acc: 0.6128 - val
Epoch 7/30
50000/50000 [==============================] - 92s 2ms/step - loss: 1.0528 - acc: 0.6304 - val
Epoch 8/30
50000/50000 [==============================] - 92s 2ms/step - loss: 1.0127 - acc: 0.6446 - val
Epoch 9/30
50000/50000 [==============================] - 92s 2ms/step - loss: 0.9756 - acc: 0.6573 - val
Epoch 10/30
50000/50000 [==============================] - 92s 2ms/step - loss: 0.9430 - acc: 0.6694 - val
Epoch 11/30
50000/50000 [==============================] - 92s 2ms/step - loss: 0.9135 - acc: 0.6782 - val
Epoch 12/30
50000/50000 [==============================] - 92s 2ms/step - loss: 0.8887 - acc: 0.6870 - val
Epoch 13/30
50000/50000 [==============================] - 92s 2ms/step - loss: 0.8608 - acc: 0.6976 - val
Epoch 14/30
50000/50000 [==============================] - 92s 2ms/step - loss: 0.8355 - acc: 0.7068 - val
Epoch 15/30
50000/50000 [==============================] - 92s 2ms/step - loss: 0.8115 - acc: 0.7168 - val
Epoch 16/30
50000/50000 [==============================] - 92s 2ms/step - loss: 0.7912 - acc: 0.7219 - val
```

```
Epoch 17/30
50000/50000 [==============================] - 92s 2ms/step - loss: 0.7716 - acc: 0.7291 - val
Epoch 18/30
50000/50000 [==============================] - 92s 2ms/step - loss: 0.7517 - acc: 0.7349 - val
Epoch 19/30
50000/50000 [==============================] - 92s 2ms/step - loss: 0.7340 - acc: 0.7437 - val
Epoch 20/30
50000/50000 [==============================] - 92s 2ms/step - loss: 0.7180 - acc: 0.7474 - val
Epoch 21/30
50000/50000 [==============================] - 92s 2ms/step - loss: 0.7015 - acc: 0.7530 - val
Epoch 22/30
50000/50000 [==============================] - 92s 2ms/step - loss: 0.6814 - acc: 0.7605 - val
Epoch 23/30
50000/50000 [==============================] - 92s 2ms/step - loss: 0.6688 - acc: 0.7647 - val
Epoch 24/30
50000/50000 [==============================] - 92s 2ms/step - loss: 0.6537 - acc: 0.7684 - val
Epoch 25/30
50000/50000 [==============================] - 92s 2ms/step - loss: 0.6401 - acc: 0.7763 - val
Epoch 26/30
50000/50000 [==============================] - 92s 2ms/step - loss: 0.6249 - acc: 0.7801 - val
Epoch 27/30
50000/50000 [==============================] - 92s 2ms/step - loss: 0.6095 - acc: 0.7871 - val
Epoch 28/30
50000/50000 [==============================] - 92s 2ms/step - loss: 0.5962 - acc: 0.7898 - val
Epoch 29/30
50000/50000 [==============================] - 92s 2ms/step - loss: 0.5844 - acc: 0.7943 - val
Epoch 30/30
50000/50000 [==============================] - 92s 2ms/step - loss: 0.5703 - acc: 0.7985 - val
```

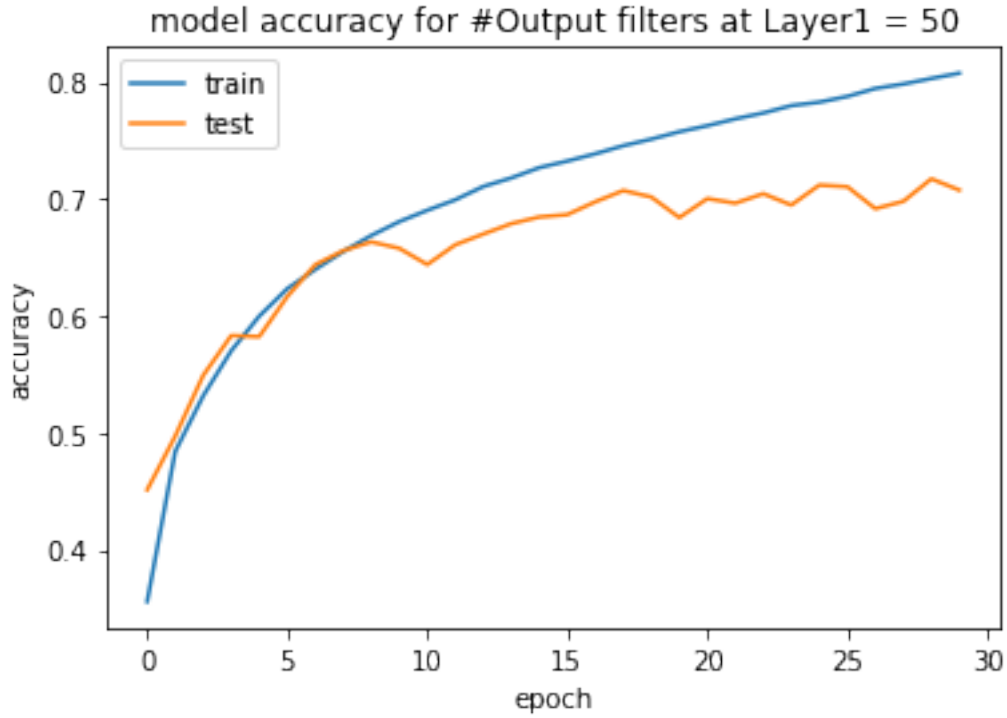

model accuracy for #Output filters at Layer1 = 25
train
test
accuracy
epoch
0.8
0.7
0.6
0.5
0.4
0
5
10
15
20
25
30

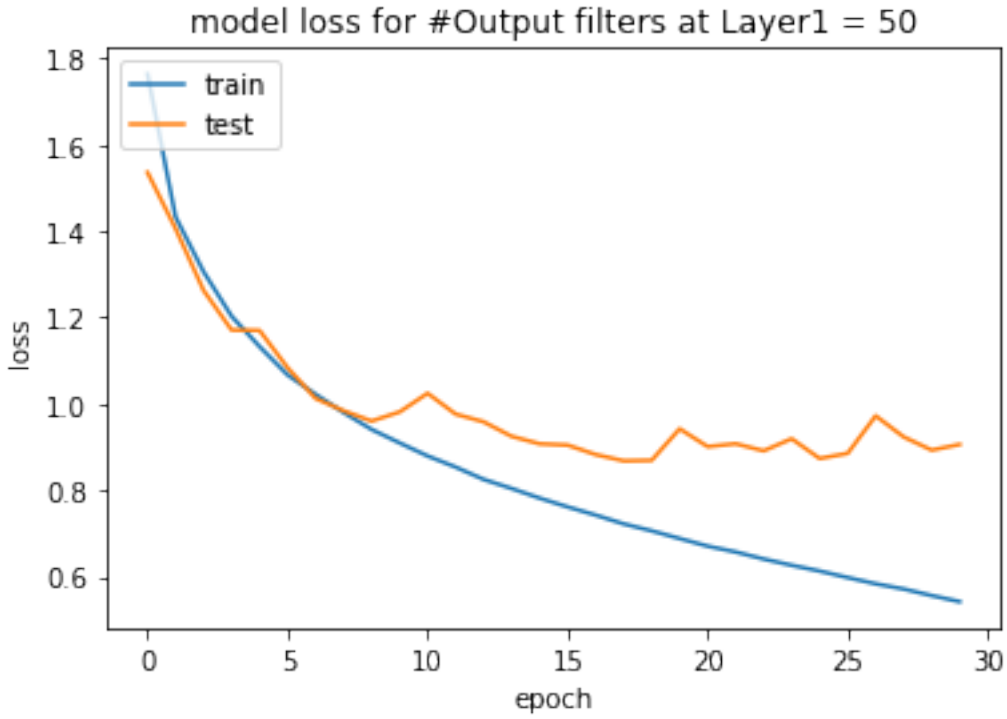

model loss for #Output filters at Layer1 = 25
train
test
loss
epoch
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0
5
10
15
20
25
30

```
Training with #Output filters at Layer1 = 50
---------------------------------

_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_19 (Conv2D)           (None, 28, 28, 50)        3800
_________________________________________________________________
activation_46 (Activation)   (None, 28, 28, 50)        0
_________________________________________________________________
max_pooling2d_19 (MaxPooling (None, 14, 14, 50)        0
_________________________________________________________________
conv2d_20 (Conv2D)           (None, 10, 10, 16)        20016
_________________________________________________________________
activation_47 (Activation)   (None, 10, 10, 16)        0
_________________________________________________________________
max_pooling2d_20 (MaxPooling (None, 5, 5, 16)          0
_________________________________________________________________
flatten_10 (Flatten)         (None, 400)               0
_________________________________________________________________
dense_28 (Dense)             (None, 120)               48120
_________________________________________________________________
activation_48 (Activation)   (None, 120)               0
_________________________________________________________________
dense_29 (Dense)             (None, 84)                10164
_________________________________________________________________
activation_49 (Activation)   (None, 84)                0
_________________________________________________________________
dense_30 (Dense)             (None, 10)                850
_________________________________________________________________
activation_50 (Activation)   (None, 10)                0
=================================================================
Total params: 82,950
Trainable params: 82,950
Non-trainable params: 0
_________________________________________________________________
None
Train on 50000 samples, validate on 10000 samples
Epoch 1/30
50000/50000 [==============================] - 148s 3ms/step - loss: 1.7639 - acc: 0.3557 - val
Epoch 2/30
50000/50000 [==============================] - 148s 3ms/step - loss: 1.4333 - acc: 0.4840 - val
Epoch 3/30
50000/50000 [==============================] - 147s 3ms/step - loss: 1.3063 - acc: 0.5317 - val
Epoch 4/30
50000/50000 [==============================] - 147s 3ms/step - loss: 1.2032 - acc: 0.5702 - val
Epoch 5/30
50000/50000 [==============================] - 147s 3ms/step - loss: 1.1328 - acc: 0.5998 - val
Epoch 6/30
```

```
50000/50000 [==============================] - 147s 3ms/step - loss: 1.0673 - acc: 0.6233 - val
Epoch 7/30
50000/50000 [==============================] - 147s 3ms/step - loss: 1.0222 - acc: 0.6398 - val
Epoch 8/30
50000/50000 [==============================] - 147s 3ms/step - loss: 0.9802 - acc: 0.6551 - val
Epoch 9/30
50000/50000 [==============================] - 147s 3ms/step - loss: 0.9409 - acc: 0.6688 - val
Epoch 10/30
50000/50000 [==============================] - 147s 3ms/step - loss: 0.9098 - acc: 0.6807 - val
Epoch 11/30
50000/50000 [==============================] - 147s 3ms/step - loss: 0.8795 - acc: 0.6904 - val
Epoch 12/30
50000/50000 [==============================] - 147s 3ms/step - loss: 0.8538 - acc: 0.6994 - val
Epoch 13/30
50000/50000 [==============================] - 147s 3ms/step - loss: 0.8252 - acc: 0.7108 - val
Epoch 14/30
50000/50000 [==============================] - 147s 3ms/step - loss: 0.8042 - acc: 0.7181 - val
Epoch 15/30
50000/50000 [==============================] - 147s 3ms/step - loss: 0.7819 - acc: 0.7269 - val
Epoch 16/30
50000/50000 [==============================] - 147s 3ms/step - loss: 0.7616 - acc: 0.7325 - val
Epoch 17/30
50000/50000 [==============================] - 147s 3ms/step - loss: 0.7426 - acc: 0.7388 - val
Epoch 18/30
50000/50000 [==============================] - 147s 3ms/step - loss: 0.7222 - acc: 0.7457 - val
Epoch 19/30
50000/50000 [==============================] - 147s 3ms/step - loss: 0.7062 - acc: 0.7513 - val
Epoch 20/30
50000/50000 [==============================] - 147s 3ms/step - loss: 0.6883 - acc: 0.7576 - val
Epoch 21/30
50000/50000 [==============================] - 147s 3ms/step - loss: 0.6707 - acc: 0.7628 - val
Epoch 22/30
50000/50000 [==============================] - 147s 3ms/step - loss: 0.6572 - acc: 0.7687 - val
Epoch 23/30
50000/50000 [==============================] - 147s 3ms/step - loss: 0.6409 - acc: 0.7737 - val
Epoch 24/30
50000/50000 [==============================] - 147s 3ms/step - loss: 0.6264 - acc: 0.7800 - val
Epoch 25/30
50000/50000 [==============================] - 147s 3ms/step - loss: 0.6130 - acc: 0.7829 - val
Epoch 26/30
50000/50000 [==============================] - 147s 3ms/step - loss: 0.5979 - acc: 0.7878 - val
Epoch 27/30
50000/50000 [==============================] - 147s 3ms/step - loss: 0.5835 - acc: 0.7947 - val
Epoch 28/30
50000/50000 [==============================] - 147s 3ms/step - loss: 0.5714 - acc: 0.7984 - val
Epoch 29/30
50000/50000 [==============================] - 147s 3ms/step - loss: 0.5562 - acc: 0.8032 - val
Epoch 30/30
```

```
50000/50000 [==============================] - 147s 3ms/step - loss: 0.5421 - acc: 0.8077 - val
```

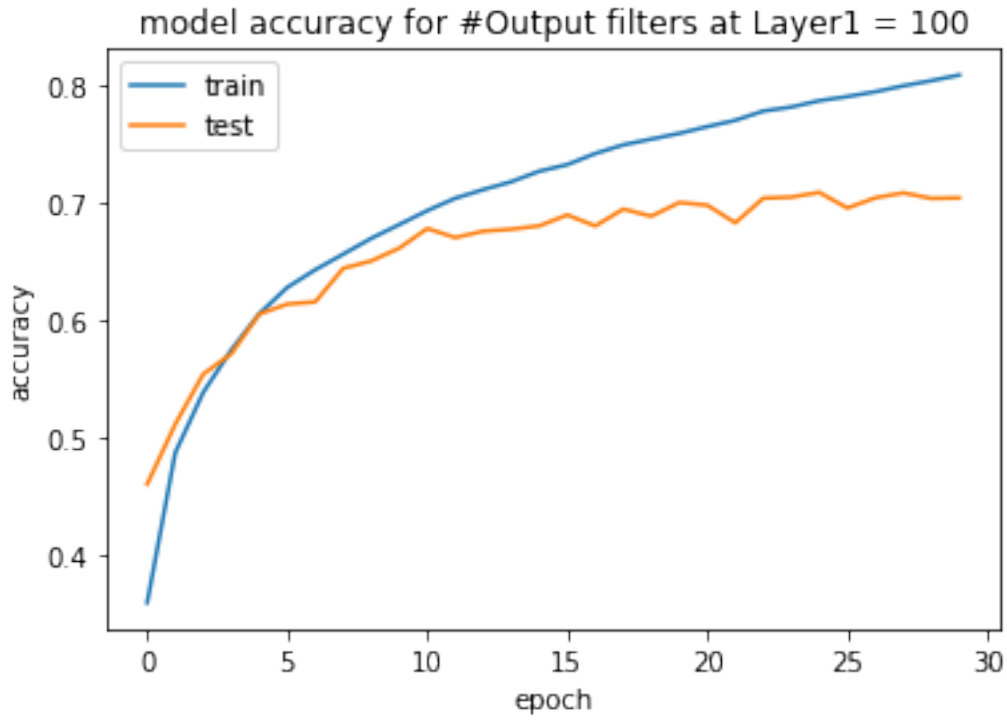


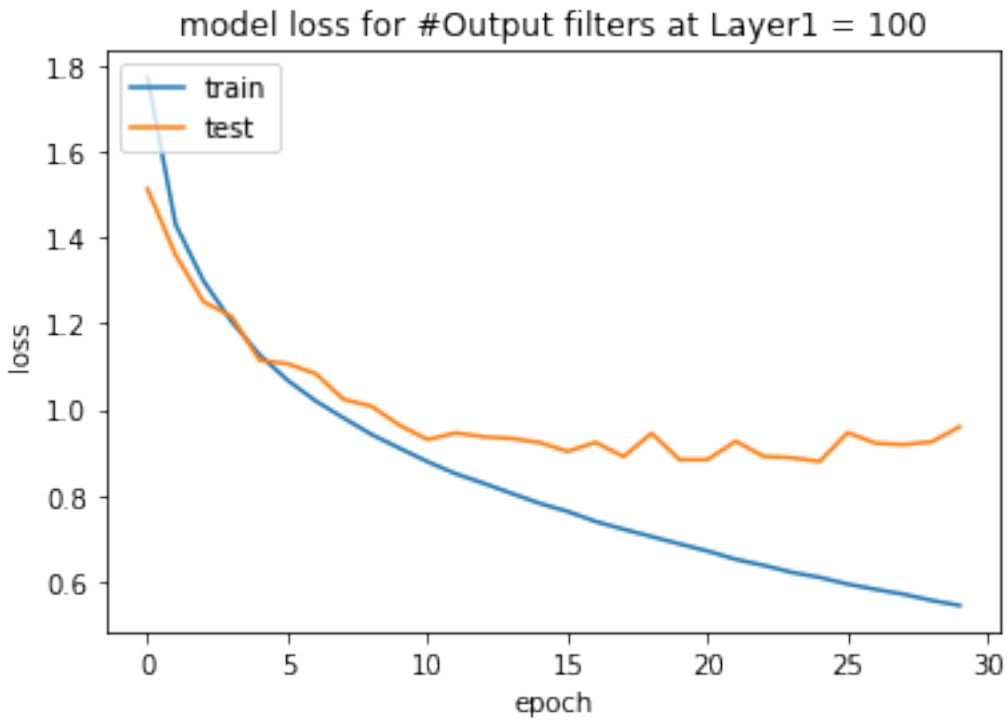


```
Training with #Output filters at Layer1 = 100
---------------------------------

_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_21 (Conv2D)           (None, 28, 28, 100)       7600
_________________________________________________________________
activation_51 (Activation)   (None, 28, 28, 100)       0
_________________________________________________________________
max_pooling2d_21 (MaxPooling (None, 14, 14, 100)       0
_________________________________________________________________
conv2d_22 (Conv2D)           (None, 10, 10, 16)        40016
_________________________________________________________________
activation_52 (Activation)   (None, 10, 10, 16)        0
_________________________________________________________________
max_pooling2d_22 (MaxPooling (None, 5, 5, 16)          0
_________________________________________________________________
flatten_11 (Flatten)         (None, 400)               0
_________________________________________________________________
dense_31 (Dense)             (None, 120)               48120
_________________________________________________________________
activation_53 (Activation)   (None, 120)               0
_________________________________________________________________
dense_32 (Dense)             (None, 84)                10164
_________________________________________________________________
activation_54 (Activation)   (None, 84)                0
_________________________________________________________________
dense_33 (Dense)             (None, 10)                850
_________________________________________________________________
activation_55 (Activation)   (None, 10)                0
=================================================================
Total params: 106,750
Trainable params: 106,750
Non-trainable params: 0
_________________________________________________________________
None
Train on 50000 samples, validate on 10000 samples
Epoch 1/30
50000/50000 [==============================] - 234s 5ms/step - loss: 1.7726 - acc: 0.3588 - val
Epoch 2/30
50000/50000 [==============================] - 233s 5ms/step - loss: 1.4308 - acc: 0.4865 - val
Epoch 3/30
50000/50000 [==============================] - 234s 5ms/step - loss: 1.2990 - acc: 0.5380 - val
Epoch 4/30
50000/50000 [==============================] - 234s 5ms/step - loss: 1.2048 - acc: 0.5741 - val
```

```
Epoch 5/30
50000/50000 [==============================] - 233s 5ms/step - loss: 1.1277 - acc: 0.6050 - val
Epoch 6/30
50000/50000 [==============================] - 233s 5ms/step - loss: 1.0682 - acc: 0.6275 - val
Epoch 7/30
50000/50000 [==============================] - 234s 5ms/step - loss: 1.0204 - acc: 0.6426 - val
Epoch 8/30
50000/50000 [==============================] - 233s 5ms/step - loss: 0.9807 - acc: 0.6559 - val
Epoch 9/30
50000/50000 [==============================] - 233s 5ms/step - loss: 0.9423 - acc: 0.6693 - val
Epoch 10/30
50000/50000 [==============================] - 233s 5ms/step - loss: 0.9104 - acc: 0.6811 - val
Epoch 11/30
50000/50000 [==============================] - 233s 5ms/step - loss: 0.8790 - acc: 0.6930 - val
Epoch 12/30
50000/50000 [==============================] - 233s 5ms/step - loss: 0.8511 - acc: 0.7035 - val
Epoch 13/30
50000/50000 [==============================] - 233s 5ms/step - loss: 0.8289 - acc: 0.7109 - val
Epoch 14/30
50000/50000 [==============================] - 233s 5ms/step - loss: 0.8054 - acc: 0.7176 - val
Epoch 15/30
50000/50000 [==============================] - 233s 5ms/step - loss: 0.7822 - acc: 0.7265 - val
Epoch 16/30
50000/50000 [==============================] - 233s 5ms/step - loss: 0.7633 - acc: 0.7322 - val
Epoch 17/30
50000/50000 [==============================] - 233s 5ms/step - loss: 0.7400 - acc: 0.7416 - val
Epoch 18/30
50000/50000 [==============================] - 233s 5ms/step - loss: 0.7220 - acc: 0.7490 - val
Epoch 19/30
50000/50000 [==============================] - 233s 5ms/step - loss: 0.7050 - acc: 0.7539 - val
Epoch 20/30
50000/50000 [==============================] - 233s 5ms/step - loss: 0.6879 - acc: 0.7588 - val
Epoch 21/30
50000/50000 [==============================] - 233s 5ms/step - loss: 0.6714 - acc: 0.7646 - val
Epoch 22/30
50000/50000 [==============================] - 233s 5ms/step - loss: 0.6521 - acc: 0.7699 - val
Epoch 23/30
50000/50000 [==============================] - 233s 5ms/step - loss: 0.6381 - acc: 0.7778 - val
Epoch 24/30
50000/50000 [==============================] - 233s 5ms/step - loss: 0.6220 - acc: 0.7813 - val
Epoch 25/30
50000/50000 [==============================] - 233s 5ms/step - loss: 0.6101 - acc: 0.7867 - val
Epoch 26/30
50000/50000 [==============================] - 233s 5ms/step - loss: 0.5946 - acc: 0.7902 - val
Epoch 27/30
50000/50000 [==============================] - 233s 5ms/step - loss: 0.5822 - acc: 0.7943 - val
Epoch 28/30
50000/50000 [==============================] - 233s 5ms/step - loss: 0.5709 - acc: 0.7993 - val
```

```
Epoch 29/30
50000/50000 [==============================] - 233s 5ms/step - loss: 0.5567 - acc: 0.8037 - val
Epoch 30/30
50000/50000 [==============================] - 233s 5ms/step - loss: 0.5449 - acc: 0.8085 - val
```





** Q8: [2 points] **

What do you observe if you increase the **number of layers** (depth of the network) ? Present your observations using plots and brief explanations.

** A8: **

Observations

1. If the Neural Network is wider and deeper the back-propagation and hyper-parameters becomes very complicated. However increasing the number of hidden layers increases the accuracy and also fit even most complex non-linear classifiers.

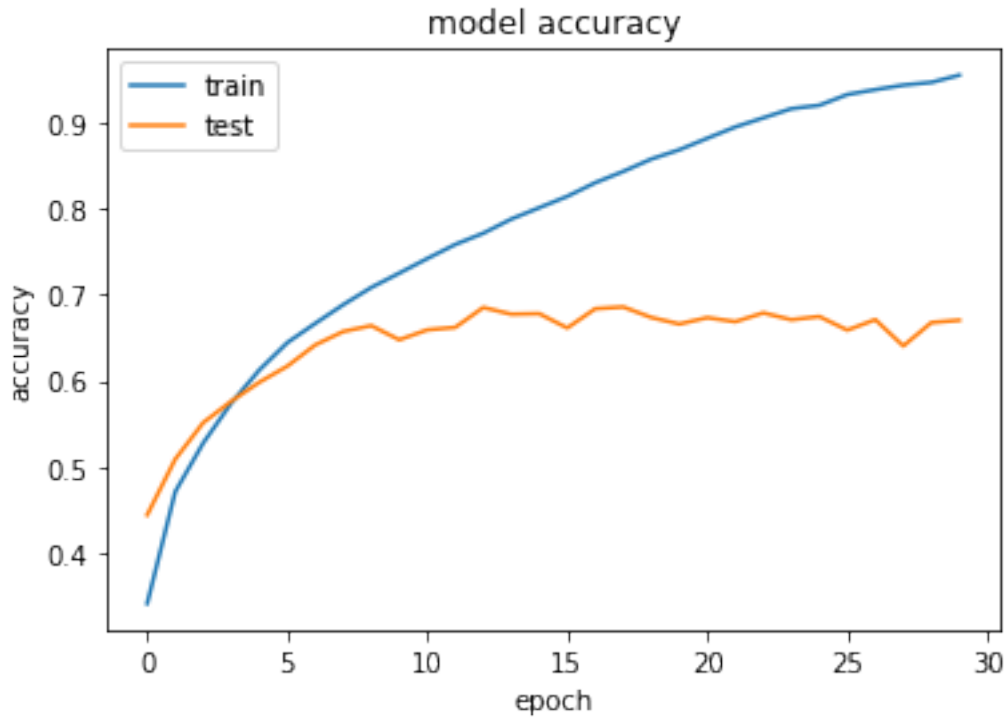
Graph below in support of the observations.

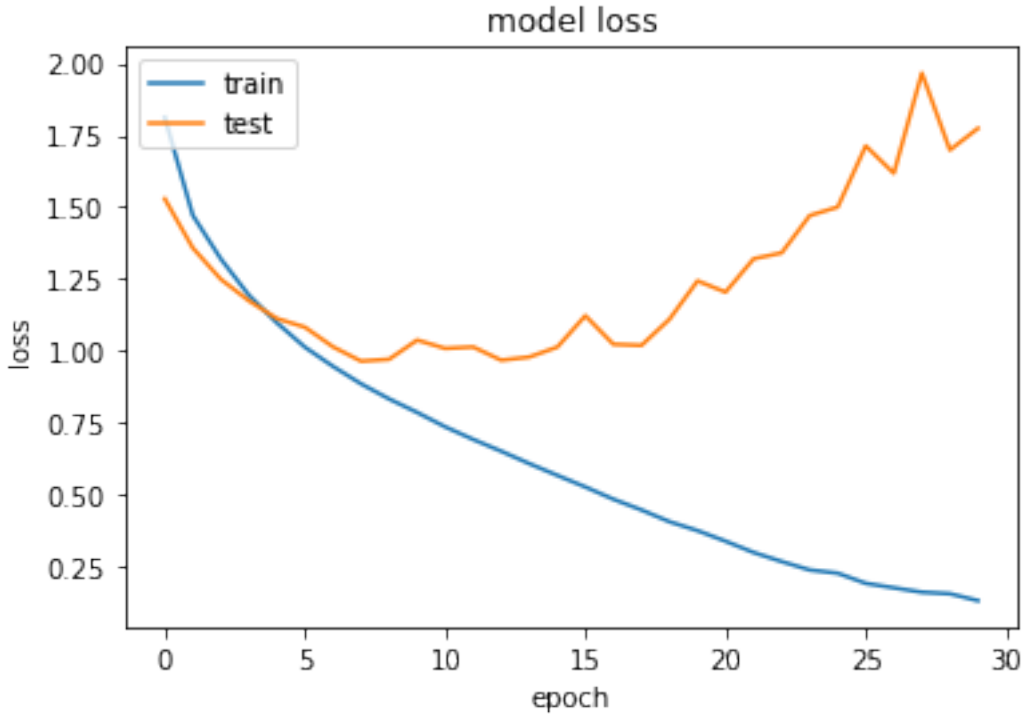
In [10]:

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_12 (Conv2D)           (None, 32, 32, 6)         456
_________________________________________________________________
activation_14 (Activation)   (None, 32, 32, 6)         0
_________________________________________________________________
max_pooling2d_9 (MaxPooling2 (None, 16, 16, 6)         0
_________________________________________________________________
conv2d_13 (Conv2D)           (None, 16, 16, 16)        2416
_________________________________________________________________
activation_15 (Activation)   (None, 16, 16, 16)        0
_________________________________________________________________
```

```
conv2d_14 (Conv2D)           (None, 16, 16, 32)        12832
_________________________________________________________________
activation_16 (Activation)   (None, 16, 16, 32)        0
_________________________________________________________________
conv2d_15 (Conv2D)           (None, 12, 12, 64)        51264
_________________________________________________________________
activation_17 (Activation)   (None, 12, 12, 64)        0
_________________________________________________________________
max_pooling2d_10 (MaxPooling (None, 6, 6, 64)          0
_________________________________________________________________
flatten_2 (Flatten)          (None, 2304)              0
_________________________________________________________________
dense_4 (Dense)              (None, 120)               276600
_________________________________________________________________
activation_18 (Activation)   (None, 120)               0
_________________________________________________________________
dense_5 (Dense)              (None, 84)                10164
_________________________________________________________________
activation_19 (Activation)   (None, 84)                0
_________________________________________________________________
dense_6 (Dense)              (None, 10)                850
_________________________________________________________________
activation_20 (Activation)   (None, 10)                0
=================================================================
Total params: 354,582
Trainable params: 354,582
Non-trainable params: 0
_________________________________________________________________
None
Train on 50000 samples, validate on 10000 samples
Epoch 1/30
50000/50000 [==============================] - 274s 5ms/step - loss: 1.8120 - acc: 0.3415 - val
Epoch 2/30
50000/50000 [==============================] - 273s 5ms/step - loss: 1.4712 - acc: 0.4712 - val
Epoch 3/30
50000/50000 [==============================] - 273s 5ms/step - loss: 1.3195 - acc: 0.5278 - val
Epoch 4/30
50000/50000 [==============================] - 273s 5ms/step - loss: 1.1932 - acc: 0.5741 - val
Epoch 5/30
50000/50000 [==============================] - 273s 5ms/step - loss: 1.0969 - acc: 0.6125 - val
Epoch 6/30
50000/50000 [==============================] - 273s 5ms/step - loss: 1.0121 - acc: 0.6443 - val
Epoch 7/30
50000/50000 [==============================] - 273s 5ms/step - loss: 0.9453 - acc: 0.6667 - val
Epoch 8/30
50000/50000 [==============================] - 273s 5ms/step - loss: 0.8846 - acc: 0.6884 - val
Epoch 9/30
50000/50000 [==============================] - 273s 5ms/step - loss: 0.8321 - acc: 0.7084 - val
```

```
Epoch 10/30
50000/50000 [==============================] - 273s 5ms/step - loss: 0.7850 - acc: 0.7251 - val
Epoch 11/30
50000/50000 [==============================] - 273s 5ms/step - loss: 0.7349 - acc: 0.7420 - val
Epoch 12/30
50000/50000 [==============================] - 273s 5ms/step - loss: 0.6909 - acc: 0.7584 - val
Epoch 13/30
50000/50000 [==============================] - 273s 5ms/step - loss: 0.6498 - acc: 0.7714 - val
Epoch 14/30
50000/50000 [==============================] - 273s 5ms/step - loss: 0.6068 - acc: 0.7879 - val
Epoch 15/30
50000/50000 [==============================] - 273s 5ms/step - loss: 0.5658 - acc: 0.8011 - val
Epoch 16/30
50000/50000 [==============================] - 273s 5ms/step - loss: 0.5254 - acc: 0.8143 - val
Epoch 17/30
50000/50000 [==============================] - 273s 5ms/step - loss: 0.4827 - acc: 0.8301 - val
Epoch 18/30
50000/50000 [==============================] - 273s 5ms/step - loss: 0.4455 - acc: 0.8432 - val
Epoch 19/30
50000/50000 [==============================] - 273s 5ms/step - loss: 0.4044 - acc: 0.8576 - val
Epoch 20/30
50000/50000 [==============================] - 273s 5ms/step - loss: 0.3734 - acc: 0.8683 - val
Epoch 21/30
50000/50000 [==============================] - 273s 5ms/step - loss: 0.3366 - acc: 0.8817 - val
Epoch 22/30
50000/50000 [==============================] - 273s 5ms/step - loss: 0.2973 - acc: 0.8948 - val
Epoch 23/30
50000/50000 [==============================] - 273s 5ms/step - loss: 0.2657 - acc: 0.9054 - val
Epoch 24/30
50000/50000 [==============================] - 273s 5ms/step - loss: 0.2364 - acc: 0.9161 - val
Epoch 25/30
50000/50000 [==============================] - 274s 5ms/step - loss: 0.2251 - acc: 0.9200 - val
Epoch 26/30
50000/50000 [==============================] - 274s 5ms/step - loss: 0.1898 - acc: 0.9325 - val
Epoch 27/30
50000/50000 [==============================] - 273s 5ms/step - loss: 0.1743 - acc: 0.9382 - val
Epoch 28/30
50000/50000 [==============================] - 273s 5ms/step - loss: 0.1589 - acc: 0.9434 - val
Epoch 29/30
50000/50000 [==============================] - 273s 5ms/step - loss: 0.1537 - acc: 0.9466 - val
Epoch 30/30
50000/50000 [==============================] - 273s 5ms/step - loss: 0.1296 - acc: 0.9550 - val
```


model accuracy
train
test
accuracy
epoch
0.4
0.5
0.6
0.7
0.8
0.9
0
5
10
15
20
25
30


model loss
train
test
loss
epoch
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
0
5
10
15
20
25
30

** Q9: [2 points] **

What do you observe if you increase the **activation functions** (tanh, relu, sigmoid) ? Present your observations using plots and brief explanations.

** A9: **

Observations .

1. The Rectified Linear Unit (ReLU) activation function gives the best accuracy in comparision with the other activation functions. It is because it eases the gradient computation.

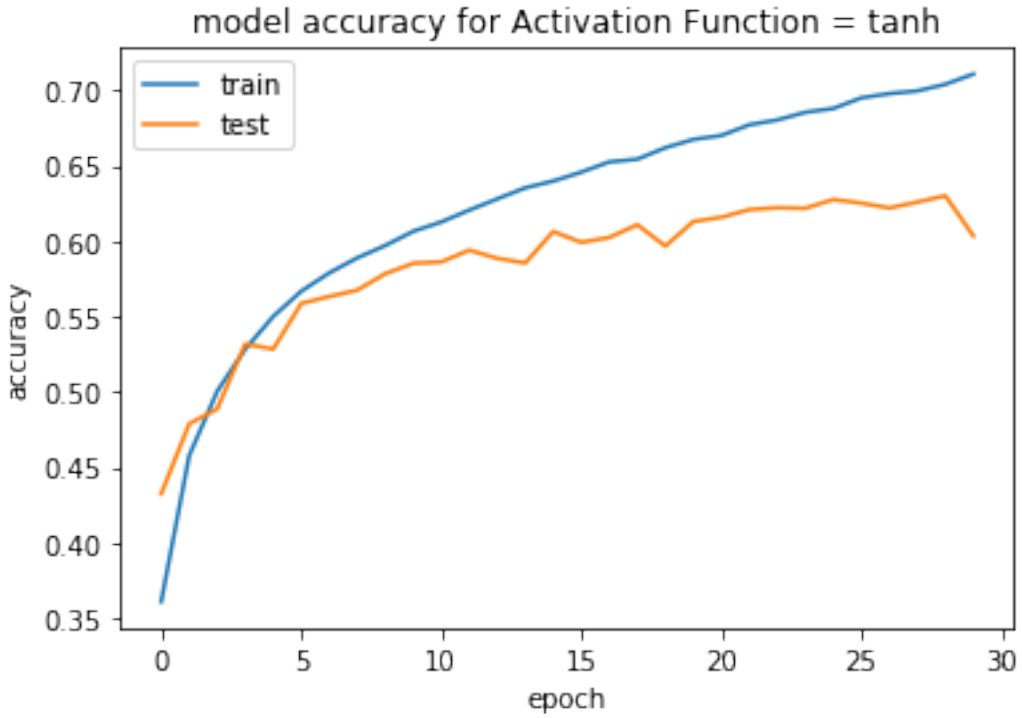
See the graphs below to support the observations.

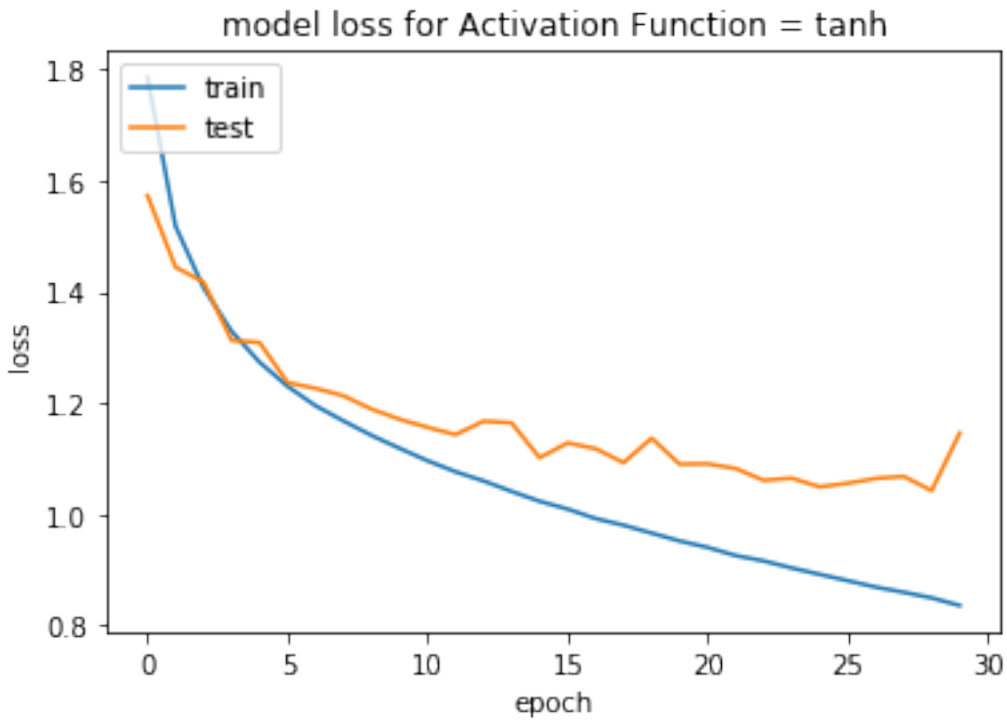
In [7]:

```
Training with Activation Function = tanh
----------------------------------

_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_1 (Conv2D)            (None, 28, 28, 6)         456
_________________________________________________________________
activation_1 (Activation)    (None, 28, 28, 6)         0
_________________________________________________________________
max_pooling2d_1 (MaxPooling2 (None, 14, 14, 6)         0
_________________________________________________________________
conv2d_2 (Conv2D)            (None, 10, 10, 16)        2416
_________________________________________________________________
activation_2 (Activation)    (None, 10, 10, 16)        0
_________________________________________________________________
max_pooling2d_2 (MaxPooling2 (None, 5, 5, 16)          0
_________________________________________________________________
flatten_1 (Flatten)          (None, 400)               0
_________________________________________________________________
dense_1 (Dense)              (None, 120)               48120
_________________________________________________________________
activation_3 (Activation)    (None, 120)               0
_________________________________________________________________
dense_2 (Dense)              (None, 84)                10164
_________________________________________________________________
activation_4 (Activation)    (None, 84)                0
_________________________________________________________________
dense_3 (Dense)              (None, 10)                850
_________________________________________________________________
activation_5 (Activation)    (None, 10)                0
=================================================================
Total params: 62,006
Trainable params: 62,006
Non-trainable params: 0
_________________________________________________________________
None
Train on 50000 samples, validate on 10000 samples
```

```
Epoch 1/30
50000/50000 [==============================] - 41s 822us/step - loss: 1.7864 - acc: 0.3608 - va
Epoch 2/30
50000/50000 [==============================] - 40s 806us/step - loss: 1.5183 - acc: 0.4577 - va
Epoch 3/30
50000/50000 [==============================] - 41s 815us/step - loss: 1.4075 - acc: 0.5004 - va
Epoch 4/30
50000/50000 [==============================] - 41s 819us/step - loss: 1.3293 - acc: 0.5282 - va
Epoch 5/30
50000/50000 [==============================] - 41s 823us/step - loss: 1.2736 - acc: 0.5500 - va
Epoch 6/30
50000/50000 [==============================] - 41s 828us/step - loss: 1.2302 - acc: 0.5667 - va
Epoch 7/30
50000/50000 [==============================] - 42s 849us/step - loss: 1.1952 - acc: 0.5788 - va
Epoch 8/30
50000/50000 [==============================] - 43s 867us/step - loss: 1.1678 - acc: 0.5888 - va
Epoch 9/30
50000/50000 [==============================] - 44s 873us/step - loss: 1.1419 - acc: 0.5970 - va
Epoch 10/30
50000/50000 [==============================] - 44s 880us/step - loss: 1.1186 - acc: 0.6064 - va
Epoch 11/30
50000/50000 [==============================] - 44s 889us/step - loss: 1.0963 - acc: 0.6126 - va
Epoch 12/30
50000/50000 [==============================] - 45s 900us/step - loss: 1.0765 - acc: 0.6205 - va
Epoch 13/30
50000/50000 [==============================] - 46s 920us/step - loss: 1.0600 - acc: 0.6279 - va
Epoch 14/30
50000/50000 [==============================] - 46s 926us/step - loss: 1.0411 - acc: 0.6352 - va
Epoch 15/30
50000/50000 [==============================] - 45s 900us/step - loss: 1.0234 - acc: 0.6398 - va
Epoch 16/30
50000/50000 [==============================] - 44s 889us/step - loss: 1.0093 - acc: 0.6456 - va
Epoch 17/30
50000/50000 [==============================] - 45s 908us/step - loss: 0.9922 - acc: 0.6525 - va
Epoch 18/30
50000/50000 [==============================] - 46s 913us/step - loss: 0.9803 - acc: 0.6542 - va
Epoch 19/30
50000/50000 [==============================] - 46s 922us/step - loss: 0.9661 - acc: 0.6618 - va
Epoch 20/30
50000/50000 [==============================] - 47s 932us/step - loss: 0.9520 - acc: 0.6674 - va
Epoch 21/30
50000/50000 [==============================] - 47s 933us/step - loss: 0.9404 - acc: 0.6699 - va
Epoch 22/30
50000/50000 [==============================] - 47s 946us/step - loss: 0.9257 - acc: 0.6771 - va
Epoch 23/30
50000/50000 [==============================] - 48s 958us/step - loss: 0.9160 - acc: 0.6803 - va
Epoch 24/30
50000/50000 [==============================] - 49s 970us/step - loss: 0.9034 - acc: 0.6853 - va
```

```
Epoch 25/30
50000/50000 [==============================] - 49s 974us/step - loss: 0.8919 - acc: 0.6879 - va
Epoch 26/30
50000/50000 [==============================] - 49s 981us/step - loss: 0.8805 - acc: 0.6949 - va
Epoch 27/30
50000/50000 [==============================] - 49s 986us/step - loss: 0.8690 - acc: 0.6977 - va
Epoch 28/30
50000/50000 [==============================] - 50s 1ms/step - loss: 0.8596 - acc: 0.6995 - val_
Epoch 29/30
50000/50000 [==============================] - 50s 1000us/step - loss: 0.8495 - acc: 0.7039 - v
Epoch 30/30
50000/50000 [==============================] - 50s 1ms/step - loss: 0.8359 - acc: 0.7107 - val_
```






```
Training with Activation Function = relu
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```
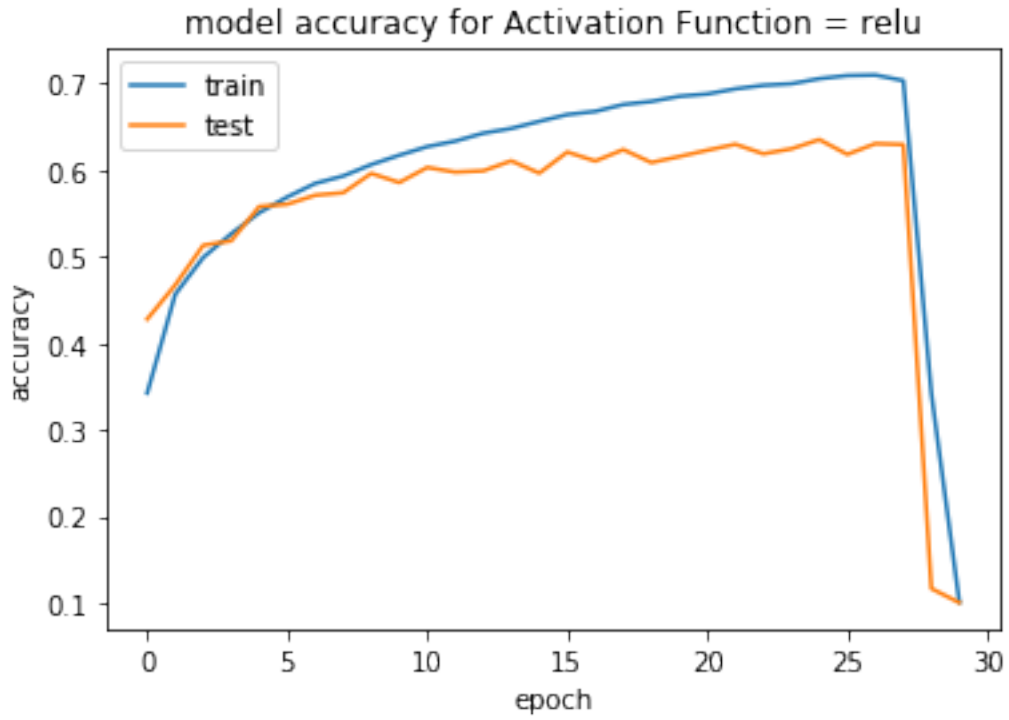
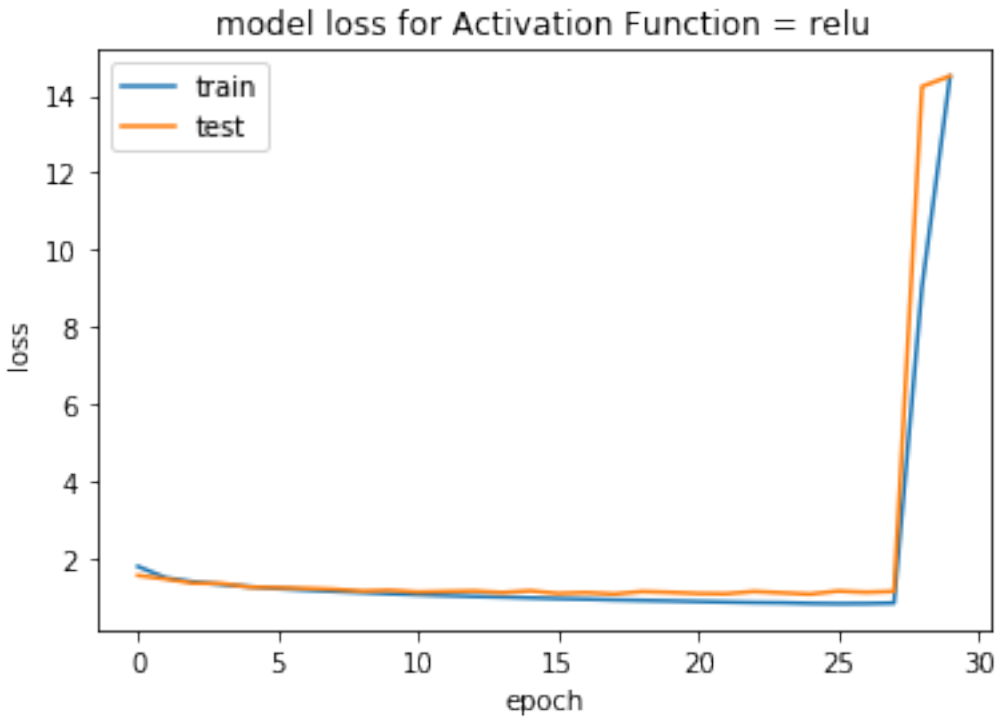

Layer (type)	Output Shape	Param #
conv2d_3 (Conv2D)	(None, 28, 28, 6)	456
activation_6 (Activation)	(None, 28, 28, 6)	0
max_pooling2d_3 (MaxPooling2	(None, 14, 14, 6)	0
conv2d_4 (Conv2D)	(None, 10, 10, 16)	2416
activation_7 (Activation)	(None, 10, 10, 16)	0
max_pooling2d_4 (MaxPooling2	(None, 5, 5, 16)	0
flatten_2 (Flatten)	(None, 400)	0
dense_4 (Dense)	(None, 120)	48120
activation_8 (Activation)	(None, 120)	0
dense_5 (Dense)	(None, 84)	10164

```
_________________________________________________________________
activation_9 (Activation)    (None, 84)                0
_________________________________________________________________
dense_6 (Dense)              (None, 10)                850
_________________________________________________________________
activation_10 (Activation)   (None, 10)                0
=================================================================
Total params: 62,006
Trainable params: 62,006
Non-trainable params: 0
_________________________________________________________________
None
Train on 50000 samples, validate on 10000 samples
Epoch 1/30
50000/50000 [==============================] - 38s 755us/step - loss: 1.7910 - acc: 0.3423 - va
Epoch 2/30
50000/50000 [==============================] - 37s 732us/step - loss: 1.4936 - acc: 0.4564 - va
Epoch 3/30
50000/50000 [==============================] - 37s 748us/step - loss: 1.3899 - acc: 0.4991 - va
Epoch 4/30
50000/50000 [==============================] - 38s 753us/step - loss: 1.3216 - acc: 0.5264 - va
Epoch 5/30
50000/50000 [==============================] - 38s 764us/step - loss: 1.2637 - acc: 0.5507 - va
Epoch 6/30
50000/50000 [==============================] - 38s 769us/step - loss: 1.2157 - acc: 0.5690 - va
Epoch 7/30
50000/50000 [==============================] - 40s 797us/step - loss: 1.1776 - acc: 0.5847 - va
Epoch 8/30
50000/50000 [==============================] - 40s 803us/step - loss: 1.1432 - acc: 0.5932 - va
Epoch 9/30
50000/50000 [==============================] - 41s 823us/step - loss: 1.1145 - acc: 0.6064 - va
Epoch 10/30
50000/50000 [==============================] - 41s 823us/step - loss: 1.0833 - acc: 0.6172 - va
Epoch 11/30
50000/50000 [==============================] - 41s 825us/step - loss: 1.0584 - acc: 0.6272 - va
Epoch 12/30
50000/50000 [==============================] - 41s 828us/step - loss: 1.0364 - acc: 0.6335 - va
Epoch 13/30
50000/50000 [==============================] - 42s 849us/step - loss: 1.0135 - acc: 0.6427 - va
Epoch 14/30
50000/50000 [==============================] - 43s 860us/step - loss: 0.9974 - acc: 0.6482 - va
Epoch 15/30
50000/50000 [==============================] - 45s 892us/step - loss: 0.9764 - acc: 0.6564 - va
Epoch 16/30
50000/50000 [==============================] - 45s 899us/step - loss: 0.9560 - acc: 0.6642 - va
Epoch 17/30
50000/50000 [==============================] - 45s 901us/step - loss: 0.9421 - acc: 0.6679 - va
Epoch 18/30
```

```
50000/50000 [==============================] - 46s 916us/step - loss: 0.9234 - acc: 0.6758 - va
Epoch 19/30
50000/50000 [==============================] - 46s 923us/step - loss: 0.9092 - acc: 0.6794 - va
Epoch 20/30
50000/50000 [==============================] - 47s 939us/step - loss: 0.8964 - acc: 0.6853 - va
Epoch 21/30
50000/50000 [==============================] - 47s 945us/step - loss: 0.8807 - acc: 0.6880 - va
Epoch 22/30
50000/50000 [==============================] - 48s 952us/step - loss: 0.8668 - acc: 0.6939 - va
Epoch 23/30
50000/50000 [==============================] - 48s 968us/step - loss: 0.8542 - acc: 0.6980 - va
Epoch 24/30
50000/50000 [==============================] - 49s 985us/step - loss: 0.8480 - acc: 0.6998 - va
Epoch 25/30
50000/50000 [==============================] - 49s 987us/step - loss: 0.8318 - acc: 0.7057 - va
Epoch 26/30
50000/50000 [==============================] - 50s 991us/step - loss: 0.8253 - acc: 0.7093 - va
Epoch 27/30
50000/50000 [==============================] - 50s 1ms/step - loss: 0.8285 - acc: 0.7099 - val_
Epoch 28/30
50000/50000 [==============================] - 50s 1ms/step - loss: 0.8405 - acc: 0.7035 - val_
Epoch 29/30
50000/50000 [==============================] - 50s 1ms/step - loss: 9.0416 - acc: 0.3421 - val_
Epoch 30/30
50000/50000 [==============================] - 50s 1ms/step - loss: 14.4970 - acc: 0.1006 - val
```



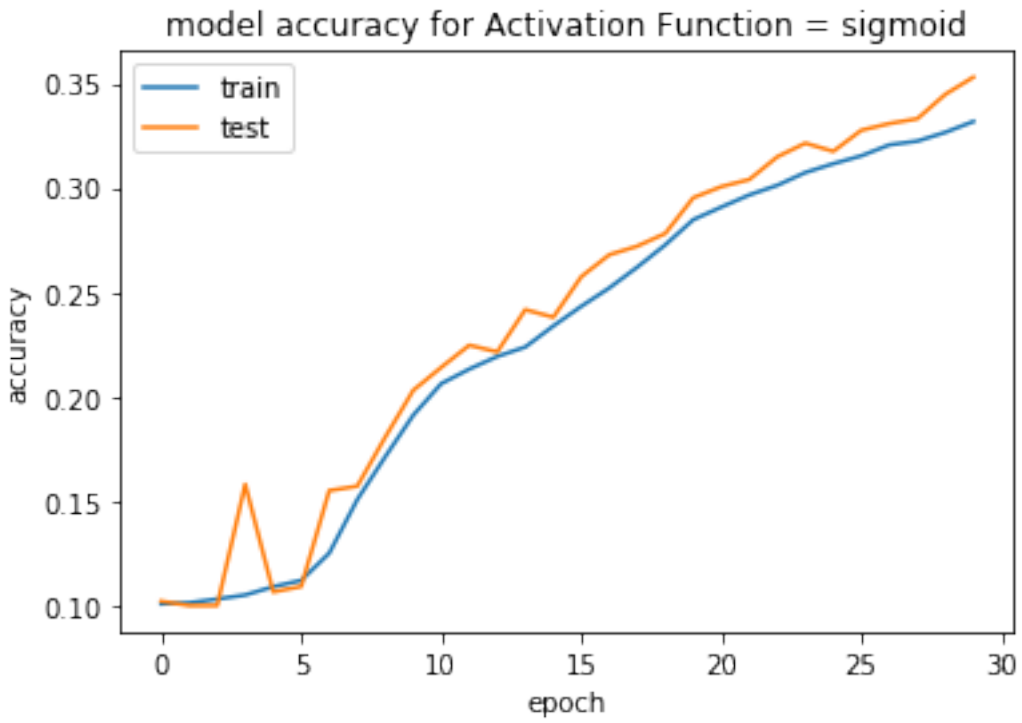


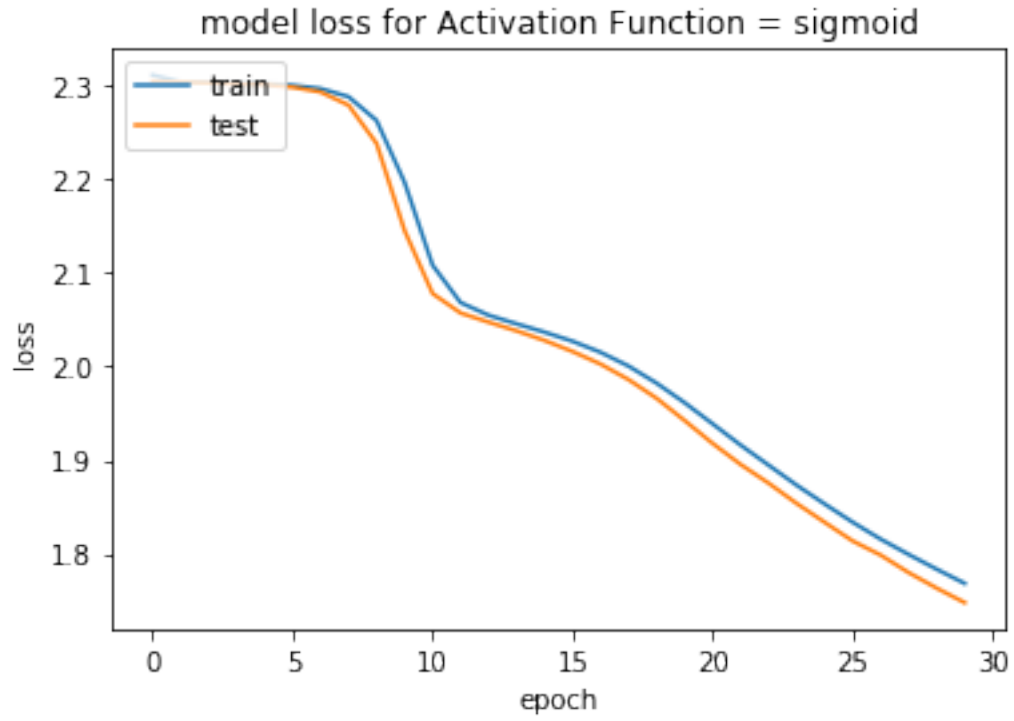

```
Training with Activation Function = sigmoid
-----------------------------------
```

Layer (type)	Output Shape	Param #
conv2d_5 (Conv2D)	(None, 28, 28, 6)	456
activation_11 (Activation)	(None, 28, 28, 6)	0
max_pooling2d_5 (MaxPooling2	(None, 14, 14, 6)	0
conv2d_6 (Conv2D)	(None, 10, 10, 16)	2416
activation_12 (Activation)	(None, 10, 10, 16)	0
max_pooling2d_6 (MaxPooling2	(None, 5, 5, 16)	0
flatten_3 (Flatten)	(None, 400)	0
dense_7 (Dense)	(None, 120)	48120

```
activation_13 (Activation)   (None, 120)              0
_________________________________________________________________
dense_8 (Dense)              (None, 84)                10164
_________________________________________________________________
activation_14 (Activation)   (None, 84)                0
_________________________________________________________________
dense_9 (Dense)              (None, 10)                850
_________________________________________________________________
activation_15 (Activation)   (None, 10)                0
=================================================================
Total params: 62,006
Trainable params: 62,006
Non-trainable params: 0
_________________________________________________________________
None
Train on 50000 samples, validate on 10000 samples
Epoch 1/30
50000/50000 [==============================] - 38s 754us/step - loss: 2.3108 - acc: 0.1008 - va
Epoch 2/30
50000/50000 [==============================] - 38s 758us/step - loss: 2.3034 - acc: 0.1013 - va
Epoch 3/30
50000/50000 [==============================] - 38s 762us/step - loss: 2.3030 - acc: 0.1031 - va
Epoch 4/30
50000/50000 [==============================] - 38s 759us/step - loss: 2.3023 - acc: 0.1050 - va
Epoch 5/30
50000/50000 [==============================] - 38s 767us/step - loss: 2.3013 - acc: 0.1090 - va
Epoch 6/30
50000/50000 [==============================] - 39s 776us/step - loss: 2.2997 - acc: 0.1120 - va
Epoch 7/30
50000/50000 [==============================] - 45s 893us/step - loss: 2.2963 - acc: 0.1251 - va
Epoch 8/30
50000/50000 [==============================] - 45s 904us/step - loss: 2.2877 - acc: 0.1507 - va
Epoch 9/30
50000/50000 [==============================] - 45s 906us/step - loss: 2.2623 - acc: 0.1712 - va
Epoch 10/30
50000/50000 [==============================] - 46s 917us/step - loss: 2.1963 - acc: 0.1911 - va
Epoch 11/30
50000/50000 [==============================] - 46s 927us/step - loss: 2.1079 - acc: 0.2062 - va
Epoch 12/30
50000/50000 [==============================] - 48s 960us/step - loss: 2.0681 - acc: 0.2132 - va
Epoch 13/30
50000/50000 [==============================] - 49s 986us/step - loss: 2.0546 - acc: 0.2192 - va
Epoch 14/30
50000/50000 [==============================] - 50s 996us/step - loss: 2.0454 - acc: 0.2237 - va
Epoch 15/30
50000/50000 [==============================] - 50s 1ms/step - loss: 2.0365 - acc: 0.2338 - val_
Epoch 16/30
50000/50000 [==============================] - 51s 1ms/step - loss: 2.0268 - acc: 0.2432 - val_
```

```
Epoch 17/30
50000/50000 [==============================] - 51s 1ms/step - loss: 2.0150 - acc: 0.2520 - val
Epoch 18/30
50000/50000 [==============================] - 51s 1ms/step - loss: 2.0003 - acc: 0.2620 - val
Epoch 19/30
50000/50000 [==============================] - 52s 1ms/step - loss: 1.9821 - acc: 0.2726 - val
Epoch 20/30
50000/50000 [==============================] - 51s 1ms/step - loss: 1.9613 - acc: 0.2847 - val
Epoch 21/30
50000/50000 [==============================] - 51s 1ms/step - loss: 1.9387 - acc: 0.2907 - val
Epoch 22/30
50000/50000 [==============================] - 52s 1ms/step - loss: 1.9160 - acc: 0.2965 - val
Epoch 23/30
50000/50000 [==============================] - 52s 1ms/step - loss: 1.8946 - acc: 0.3011 - val
Epoch 24/30
50000/50000 [==============================] - 53s 1ms/step - loss: 1.8733 - acc: 0.3073 - val
Epoch 25/30
50000/50000 [==============================] - 53s 1ms/step - loss: 1.8532 - acc: 0.3115 - val
Epoch 26/30
50000/50000 [==============================] - 53s 1ms/step - loss: 1.8338 - acc: 0.3153 - val
Epoch 27/30
50000/50000 [==============================] - 53s 1ms/step - loss: 1.8157 - acc: 0.3205 - val
Epoch 28/30
50000/50000 [==============================] - 53s 1ms/step - loss: 1.7994 - acc: 0.3223 - val
Epoch 29/30
50000/50000 [==============================] - 53s 1ms/step - loss: 1.7836 - acc: 0.3265 - val
Epoch 30/30
50000/50000 [==============================] - 54s 1ms/step - loss: 1.7685 - acc: 0.3317 - val
```


model accuracy for Activation Function = sigmoid
train
test
accuracy
epoch
0.35
0.30
0.25
0.20
0.15
0.10
0
5
10
15
20
25
30


model loss for Activation Function = sigmoid
train
test
loss
epoch
2.3
2.2
2.1
2.0
1.9
1.8
0
5
10
15
20
25
30

** Q10: [1 points] **

CNN training requires lot of training data. In the absence of large training data, a common practice is to use synthetic data using operations such as flipping, scaling, etc. Can you think of any other two operations techniques that can help to increase the training set? Demonstrate these effects with sufficient explanation.

** A10: **

To increase the training data we can use techniques like 1. Rotating the images - clockwise and anti clockwise. 2. Taking mirror images about horizontal and vertical axes (increases the training set x4 times) 3. Adding a little white noise.

Using Caffe, mirroring and random cropping are possible without changing actual DB.