Convolutional Neural Networks

CNN's of different architectures

In [2]:

```
from __future__ import print_function
import keras
from keras.datasets import mnist
from keras.models import Sequential
from keras.layers import Dense, Dropout, Flatten
from keras.layers import Convolution2D, MaxPooling2D
from keras.layers.normalization import BatchNormalization
from keras import backend as K
import matplotlib.pyplot as plt
import numpy as np
import time
```

```
Using TensorFlow backend.
```

The default version of TensorFlow in Colab will soon switch to TensorFlow 2.x.
We recommend you upgrade now or ensure your notebook will continue to use TensorFlow 1.x via the `%tensorflow_version 1.x` magic: more info.

In [3]:

```
# input image dimensions
img_rows, img_cols = 28, 28

# the data, split between train and test sets
(x_train, y_train), (x_test, y_test) = mnist.load_data()

if K.image_data_format() == 'channels_first':
    x_train = x_train.reshape(x_train.shape[0], 1, img_rows, img_cols)
    x_test = x_test.reshape(x_test.shape[0], 1, img_rows, img_cols)
    input_shape = (1, img_rows, img_cols)
else:
    x_train = x_train.reshape(x_train.shape[0], img_rows, img_cols, 1)
    x_test = x_test.reshape(x_test.shape[0], img_rows, img_cols, 1)
    input_shape = (img_rows, img_cols, 1)
```

```
Downloading data from https://s3.amazonaws.com/img-datasets/mnist.npz
11493376/11490434 [==============================] - 1s 0us/step
```

In [4]:

```
num_classes = 10

x_train = x_train.astype('float32')
x_test = x_test.astype('float32')
x_train /= 255
x_test /= 255
print('x_train shape:', x_train.shape)
print(x_train.shape[0], 'train samples')
print(x_test.shape[0], 'test samples')

# convert class vectors to binary class matrices
y_train = keras.utils.to_categorical(y_train, num_classes)
y_test = keras.utils.to_categorical(y_test, num_classes)
```

```
x_train shape: (60000, 28, 28, 1)
60000 train samples
10000 test samples
```

In [0]:

```
# https://gist.github.com/greydanus/f6eee59eaf1d90fcb3b534a25362cea4
# https://stackoverflow.com/a/14434334
# this function is used to update the plots for each epoch and error
def plt_dynamic(x, vy, ty, ax, fig, colors=['b']):
    ax.plot(x, vy, 'b', label="Validation Loss")
    ax.plot(x, ty, 'r', label="Train Loss")
    plt.legend()
    plt.grid()
    fig.canvas.draw()
```

1. CNN Architecture - 1

1.1 Activation: Relu

1.1.1 With Batch Normalization and Dropout

In [0]:

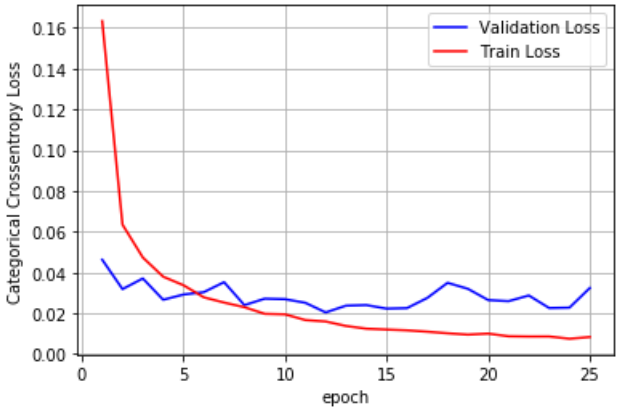
```
def build_model_BN_1(input_shape, classes):
  model = Sequential()

  model.add(Convolution2D(64, (3,3), activation='relu', kernel_initializer='he_normal', padding='valid', input_shape=input_shape))
  model.add(Convolution2D(128, (3,3), activation='relu', kernel_initializer='he_normal', padding='same'))
  model.add(Convolution2D(32, (3,3), activation='relu', kernel_initializer='he_normal', padding='same'))
  model.add(MaxPooling2D(2,2))
  model.add(BatchNormalization())
  model.add(Dropout(0.25))

  model.add(Flatten())
  model.add(Dense(128, activation='relu', kernel_initializer='he_normal'))
  model.add(BatchNormalization())
  model.add(Dropout(0.5))
  model.add(Dense(classes, activation='softmax'))

  return model
```

In [0]:

```
def run_model_BN_1():
  batch_size = 128
  epochs = 25

  model = build_model_BN_1(input_shape, num_classes)
  model.compile(loss=keras.losses.categorical_crossentropy,
              optimizer=keras.optimizers.Adadelta(),
              metrics=['accuracy'])

  history = model.fit(x_train, y_train,
            batch_size=batch_size,
            epochs=epochs,
            verbose=1,
            validation_data=(x_test, y_test))
  score = model.evaluate(x_test, y_test, verbose=0)
  print('Test Score: ', score[0])
  print('Test Accuracy: ', score[1])

  fig,ax = plt.subplots(1,1)
  ax.set_xlabel('epoch') ; ax.set_ylabel('Categorical Crossentropy Loss')

  # list of epoch numbers
  x = list(range(1,epochs+1))

  vy = history.history['val_loss']
  ty = history.history['loss']
  plt_dynamic(x, vy, ty, ax, fig)

run_model_BN_1()
```

```
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:66: The name tf.get_default_graph is deprecated. Plea
se use tf.compat.v1.get_default_graph instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:541: The name tf.placeholder is deprecated. Please us
e tf.compat.v1.placeholder instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:4432: The name tf.random_uniform is deprecated. Pleas
e use tf.random.uniform instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:4267: The name tf.nn.max_pool is deprecated. Please u
se tf.nn.max_pool2d instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:190: The name tf.get_default_session is deprecated. P
lease use tf.compat.v1.get_default_session instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:197: The name tf.ConfigProto is deprecated. Please us
e tf.compat.v1.ConfigProto instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:203: The name tf.Session is deprecated. Please use tf
.compat.v1.Session instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:207: The name tf.global_variables is deprecated. Plea
se use tf.compat.v1.global_variables instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:216: The name tf.is_variable_initialized is
deprecated. Please use tf.compat.v1.is_variable_initialized instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:223: The name tf.variables_initializer is deprecated.
Please use tf.compat.v1.variables_initializer instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:2041: The name tf.nn.fused_batch_norm is deprecated.
Please use tf.compat.v1.nn.fused_batch_norm instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:148: The name tf.placeholder_with_default is
deprecated. Please use tf.compat.v1.placeholder_with_default instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:3733: calling dropout (from
tensorflow.python.ops.nn_ops) with keep_prob is deprecated and will be removed in a future
version.
Instructions for updating:
Please use `rate` instead of `keep_prob`. Rate should be set to `rate = 1 - keep_prob`.
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/optimizers.py:793: The name t
f.train.Optimizer is deprecated. Please use tf.compat.v1.train.Optimizer instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:3576: The name tf.log is deprecated. Please use tf.ma
th.log instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/tensorflow_core/python/ops/math_grad.py:1424: where (from
tensorflow.python.ops.array_ops) is deprecated and will be removed in a future version.
Instructions for updating:
Use tf.where in 2.0, which has the same broadcast rule as np.where
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:1033: The name tf.assign_add is deprecated. Please us
e tf.compat.v1.assign_add instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:1020: The name tf.assign is deprecated. Please use tf
.compat.v1.assign instead.

Train on 60000 samples, validate on 10000 samples
Epoch 1/25
```

```
60000/60000 [==============================] - 855s 14ms/step - loss: 0.1632 - acc: 0.9506 - val_l
oss: 0.0463 - val_acc: 0.9849
Epoch 2/25
60000/60000 [==============================] - 850s 14ms/step - loss: 0.0635 - acc: 0.9815 - val_l
oss: 0.0319 - val_acc: 0.9894
Epoch 3/25
60000/60000 [==============================] - 848s 14ms/step - loss: 0.0474 - acc: 0.9854 - val_l
oss: 0.0371 - val_acc: 0.9882
Epoch 4/25
60000/60000 [==============================] - 844s 14ms/step - loss: 0.0380 - acc: 0.9883 - val_l
oss: 0.0266 - val_acc: 0.9906
Epoch 5/25
60000/60000 [==============================] - 846s 14ms/step - loss: 0.0338 - acc: 0.9895 - val_l
oss: 0.0292 - val_acc: 0.9907
Epoch 6/25
60000/60000 [==============================] - 848s 14ms/step - loss: 0.0278 - acc: 0.9913 - val_l
oss: 0.0304 - val_acc: 0.9904
Epoch 7/25
60000/60000 [==============================] - 844s 14ms/step - loss: 0.0253 - acc: 0.9920 - val_l
oss: 0.0353 - val_acc: 0.9894
Epoch 8/25
60000/60000 [==============================] - 845s 14ms/step - loss: 0.0230 - acc: 0.9929 - val_l
oss: 0.0240 - val_acc: 0.9918
Epoch 9/25
60000/60000 [==============================] - 849s 14ms/step - loss: 0.0197 - acc: 0.9936 - val_l
oss: 0.0272 - val_acc: 0.9922
Epoch 10/25
60000/60000 [==============================] - 846s 14ms/step - loss: 0.0195 - acc: 0.9940 - val_l
oss: 0.0269 - val_acc: 0.9912
Epoch 11/25
60000/60000 [==============================] - 839s 14ms/step - loss: 0.0167 - acc: 0.9948 - val_l
oss: 0.0252 - val_acc: 0.9917
Epoch 12/25
60000/60000 [==============================] - 840s 14ms/step - loss: 0.0160 - acc: 0.9949 - val_l
oss: 0.0204 - val_acc: 0.9940
Epoch 13/25
60000/60000 [==============================] - 842s 14ms/step - loss: 0.0138 - acc: 0.9956 - val_l
oss: 0.0238 - val_acc: 0.9921
Epoch 14/25
60000/60000 [==============================] - 846s 14ms/step - loss: 0.0125 - acc: 0.9961 - val_l
oss: 0.0240 - val_acc: 0.9935
Epoch 15/25
60000/60000 [==============================] - 846s 14ms/step - loss: 0.0120 - acc: 0.9963 - val_l
oss: 0.0223 - val_acc: 0.9934
Epoch 16/25
60000/60000 [==============================] - 843s 14ms/step - loss: 0.0117 - acc: 0.9962 - val_l
oss: 0.0225 - val_acc: 0.9938
Epoch 17/25
60000/60000 [==============================] - 841s 14ms/step - loss: 0.0110 - acc: 0.9965 - val_l
oss: 0.0275 - val_acc: 0.9920
Epoch 18/25
60000/60000 [==============================] - 841s 14ms/step - loss: 0.0102 - acc: 0.9967 - val_l
oss: 0.0350 - val_acc: 0.9909
Epoch 19/25
60000/60000 [==============================] - 841s 14ms/step - loss: 0.0096 - acc: 0.9969 - val_l
oss: 0.0320 - val_acc: 0.9914
Epoch 20/25
60000/60000 [==============================] - 834s 14ms/step - loss: 0.0101 - acc: 0.9966 - val_l
oss: 0.0265 - val_acc: 0.9923
Epoch 21/25
60000/60000 [==============================] - 837s 14ms/step - loss: 0.0087 - acc: 0.9971 - val_l
oss: 0.0259 - val_acc: 0.9934
Epoch 22/25
60000/60000 [==============================] - 841s 14ms/step - loss: 0.0086 - acc: 0.9970 - val_l
oss: 0.0287 - val_acc: 0.9932
Epoch 23/25
60000/60000 [==============================] - 832s 14ms/step - loss: 0.0086 - acc: 0.9974 - val_l
oss: 0.0226 - val_acc: 0.9935
Epoch 24/25
60000/60000 [==============================] - 832s 14ms/step - loss: 0.0075 - acc: 0.9975 - val_l
oss: 0.0228 - val_acc: 0.9934
Epoch 25/25
60000/60000 [==============================] - 830s 14ms/step - loss: 0.0084 - acc: 0.9971 - val_l
oss: 0.0324 - val_acc: 0.9908
Test Score:  0.03241688067764 18
Test Accuracy:  0.9908
```



In [0]:

```
```

1.1.2 Without Batch Normalization and Dropout

In [0]:

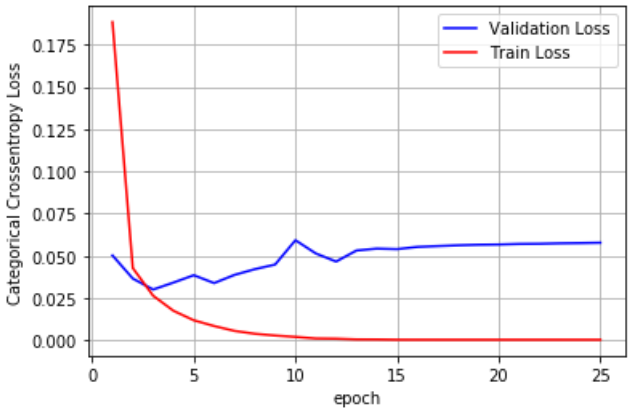
```
def build_model_1(input_shape, classes):
  model = Sequential()

  model.add(Convolution2D(64, (3,3), activation='relu', kernel_initializer='he_normal', padding='valid', input_shape=input_shape))
  model.add(Convolution2D(128, (3,3), activation='relu', kernel_initializer='he_normal', padding='same'))
  model.add(Convolution2D(32, (3,3), activation='relu', kernel_initializer='he_normal', padding='same'))
  model.add(MaxPooling2D(2,2))

  model.add(Flatten())
  model.add(Dense(128, activation='relu'. kernel_initializer='he_normal'))
  model.add(Dense(classes, activation='softmax'))

  return model
```

In [0]:

```
def run_model_1():
  batch_size = 128
  epochs = 25

  model = build_model_1(input_shape, num_classes)
  model.compile(loss=keras.losses.categorical_crossentropy,
              optimizer=keras.optimizers.Adadelta(),
              metrics=['accuracy'])

  history = model.fit(x_train, y_train,
            batch_size=batch_size,
            epochs=epochs,
            verbose=1,
            validation_data=(x_test, y_test))
  score = model.evaluate(x_test, y_test, verbose=0)
  print('Test Score: ', score[0])
  print('Test Accuracy: ', score[1])

  fig,ax = plt.subplots(1,1)
  ax.set_xlabel('epoch') ; ax.set_ylabel('Categorical Crossentropy Loss')

  # list of epoch numbers
  x = list(range(1,epochs+1))

  vy = history.history['val_loss']
  ty = history.history['loss']
  plt_dynamic(x, vy, ty, ax, fig)

run_model_1()
```

```
Train on 60000 samples, validate on 10000 samples
Epoch 1/25
60000/60000 [==============================] - 814s 14ms/step - loss: 0.1884 - acc: 0.9425 - val_l
oss: 0.0502 - val_acc: 0.9838
Epoch 2/25
60000/60000 [==============================] - 817s 14ms/step - loss: 0.0427 - acc: 0.9865 - val_l
oss: 0.0365 - val_acc: 0.9869
Epoch 3/25
60000/60000 [==============================] - 818s 14ms/step - loss: 0.0263 - acc: 0.9920 - val_l
oss: 0.0300 - val_acc: 0.9911
Epoch 4/25
60000/60000 [==============================] - 816s 14ms/step - loss: 0.0174 - acc: 0.9948 - val_l
oss: 0.0341 - val_acc: 0.9900
Epoch 5/25
60000/60000 [==============================] - 815s 14ms/step - loss: 0.0118 - acc: 0.9965 - val_l
oss: 0.0385 - val_acc: 0.9892
Epoch 6/25
60000/60000 [==============================] - 815s 14ms/step - loss: 0.0084 - acc: 0.9975 - val_l
oss: 0.0338 - val_acc: 0.9906
Epoch 7/25
60000/60000 [==============================] - 821s 14ms/step - loss: 0.0055 - acc: 0.9983 - val_l
oss: 0.0387 - val_acc: 0.9906
Epoch 8/25
60000/60000 [==============================] - 814s 14ms/step - loss: 0.0038 - acc: 0.9990 - val_l
oss: 0.0421 - val_acc: 0.9903
Epoch 9/25
60000/60000 [==============================] - 818s 14ms/step - loss: 0.0028 - acc: 0.9992 - val_l
oss: 0.0448 - val_acc: 0.9911
Epoch 10/25
60000/60000 [==============================] - 810s 14ms/step - loss: 0.0020 - acc: 0.9994 - val_l
oss: 0.0592 - val_acc: 0.9882
Epoch 11/25
60000/60000 [==============================] - 811s 14ms/step - loss: 0.0010 - acc: 0.9998 - val_l
oss: 0.0514 - val_acc: 0.9919
Epoch 12/25
60000/60000 [==============================] - 808s 13ms/step - loss: 8.8618e-04 - acc: 0.9998 - v
al_loss: 0.0466 - val_acc: 0.9915
Epoch 13/25
60000/60000 [==============================] - 795s 13ms/step - loss: 4.6773e-04 - acc: 0.9999 - v
al_loss: 0.0531 - val_acc: 0.9908
Epoch 14/25
60000/60000 [==============================] - 771s 13ms/step - loss: 4.2531e-04 - acc: 0.9999 - v
al_loss: 0.0543 - val_acc: 0.9918
Epoch 15/25
60000/60000 [==============================] - 770s 13ms/step - loss: 2.8468e-04 - acc: 1.0000 - v
al_loss: 0.0539 - val_acc: 0.9917
Epoch 16/25
60000/60000 [==============================] - 765s 13ms/step - loss: 2.7798e-04 - acc: 1.0000 - v
al_loss: 0.0553 - val_acc: 0.9914
Epoch 17/25
60000/60000 [==============================] - 769s 13ms/step - loss: 2.7328e-04 - acc: 1.0000 - v
al_loss: 0.0558 - val_acc: 0.9914
Epoch 18/25
60000/60000 [==============================] - 768s 13ms/step - loss: 2.7191e-04 - acc: 1.0000 - v
al_loss: 0.0562 - val_acc: 0.9915
Epoch 19/25
60000/60000 [==============================] - 771s 13ms/step - loss: 2.7160e-04 - acc: 1.0000 - v
al_loss: 0.0565 - val_acc: 0.9914
Epoch 20/25
60000/60000 [==============================] - 770s 13ms/step - loss: 2.7140e-04 - acc: 1.0000 - v
al_loss: 0.0567 - val_acc: 0.9913
Epoch 21/25
60000/60000 [==============================] - 769s 13ms/step - loss: 2.7101e-04 - acc: 1.0000 - v
al_loss: 0.0570 - val_acc: 0.9913
Epoch 22/25
60000/60000 [==============================] - 769s 13ms/step - loss: 2.7080e-04 - acc: 1.0000 - v
al_loss: 0.0571 - val_acc: 0.9915
Epoch 23/25
60000/60000 [==============================] - 769s 13ms/step - loss: 2.7064e-04 - acc: 1.0000 - v
al_loss: 0.0574 - val_acc: 0.9913
Epoch 24/25
60000/60000 [==============================] - 768s 13ms/step - loss: 2.7048e-04 - acc: 1.0000 - v
al_loss: 0.0575 - val_acc: 0.9914
Epoch 25/25
60000/60000 [==============================] - 771s 13ms/step - loss: 2.7038e-04 - acc: 1.0000 - v
al_loss: 0.0577 - val_acc: 0.9913
```

```
al_loss: 0.0577 - val_acc: 0.9913
Test Score:  0.057738292940303 84
Test Accuracy:  0.9913
```



In [0]:

```
```

1.2 Activation: Sigmoid

1.2.1 With Batch Normalization and Dropout

In [0]:

```
def build_model_BN_1(input_shape, classes):
  model = Sequential()

  model.add(Convolution2D(64, (3,3), activation='sigmoid', kernel_initializer='glorot_normal', padd
ing='valid', input_shape=input_shape))
  model.add(Convolution2D(128, (3,3), activation='sigmoid', kernel_initializer='glorot_normal', pad
ding='same'))
  model.add(Convolution2D(32, (3,3), activation='sigmoid', kernel_initializer='glorot_normal', padd
ing='same'))
  model.add(MaxPooling2D(2,2))
  model.add(BatchNormalization())
  model.add(Dropout(0.25))

  model.add(Flatten())
  model.add(Dense(128, activation='sigmoid', kernel_initializer='glorot_normal'))
  model.add(BatchNormalization())
  model.add(Dropout(0.5))
  model.add(Dense(classes, activation='softmax'))

  return model
```

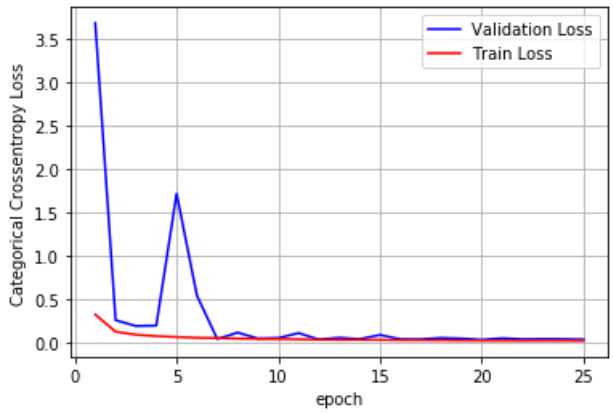
In [8]:

```
def run_model_BN_1():
  batch_size = 128
  epochs = 25

  model = build_model_BN_1(input_shape, num_classes)
  model.compile(loss=keras.losses.categorical_crossentropy,
                optimizer=keras.optimizers.Adadelta(),
                metrics=['accuracy'])

  history = model.fit(x_train, y_train,
            batch_size=batch_size,
            epochs=epochs,
            verbose=1,
            validation_data=(x_test, y_test))
  score = model.evaluate(x_test, y_test, verbose=0)
  print('Test Score: ', score[0])
  print('Test Accuracy: ', score[1])

  fig,ax = plt.subplots(1,1)
```

```
  fig,ax = plt.subplots(1,1)
  ax.set_xlabel('epoch') ; ax.set_ylabel('Categorical Crossentropy Loss')

  # list of epoch numbers
  x = list(range(1,epochs+1))

  vy = history.history['val_loss']
  ty = history.history['loss']
  plt_dynamic(x, vy, ty, ax, fig)

run_model_BN_1()
```

```
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:2041: The name tf.nn.fused_batch_norm is deprecated.
Please use tf.compat.v1.nn.fused_batch_norm instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:148: The name tf.placeholder_with_default is
deprecated. Please use tf.compat.v1.placeholder_with_default instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:3733: calling dropout (from
tensorflow.python.ops.nn_ops) with keep_prob is deprecated and will be removed in a future
version.
Instructions for updating:
Please use `rate` instead of `keep_prob`. Rate should be set to `rate = 1 - keep_prob`.
Train on 60000 samples, validate on 10000 samples
Epoch 1/25
60000/60000 [==============================] - 759s 13ms/step - loss: 0.3225 - acc: 0.9033 - val_l
oss: 3.6792 - val_acc: 0.3160
Epoch 2/25
60000/60000 [==============================] - 760s 13ms/step - loss: 0.1252 - acc: 0.9627 - val_l
oss: 0.2579 - val_acc: 0.9218
Epoch 3/25
60000/60000 [==============================] - 758s 13ms/step - loss: 0.0898 - acc: 0.9729 - val_l
oss: 0.1908 - val_acc: 0.9449
Epoch 4/25
60000/60000 [==============================] - 758s 13ms/step - loss: 0.0744 - acc: 0.9774 - val_l
oss: 0.1950 - val_acc: 0.9384
Epoch 5/25
60000/60000 [==============================] - 757s 13ms/step - loss: 0.0641 - acc: 0.9803 - val_l
oss: 1.7160 - val_acc: 0.6800
Epoch 6/25
60000/60000 [==============================] - 760s 13ms/step - loss: 0.0551 - acc: 0.9835 - val_l
oss: 0.5406 - val_acc: 0.8626
Epoch 7/25
60000/60000 [==============================] - 760s 13ms/step - loss: 0.0519 - acc: 0.9837 - val_l
oss: 0.0406 - val_acc: 0.9867
Epoch 8/25
60000/60000 [==============================] - 765s 13ms/step - loss: 0.0462 - acc: 0.9857 - val_l
oss: 0.1149 - val_acc: 0.9660
Epoch 9/25
60000/60000 [==============================] - 764s 13ms/step - loss: 0.0432 - acc: 0.9866 - val_l
oss: 0.0468 - val_acc: 0.9864
Epoch 10/25
60000/60000 [==============================] - 763s 13ms/step - loss: 0.0413 - acc: 0.9866 - val_l
oss: 0.0527 - val_acc: 0.9836
Epoch 11/25
60000/60000 [==============================] - 762s 13ms/step - loss: 0.0372 - acc: 0.9878 - val_l
oss: 0.1094 - val_acc: 0.9703
Epoch 12/25
60000/60000 [==============================] - 763s 13ms/step - loss: 0.0345 - acc: 0.9891 - val_l
oss: 0.0347 - val_acc: 0.9888
Epoch 13/25
60000/60000 [==============================] - 762s 13ms/step - loss: 0.0321 - acc: 0.9900 - val_l
oss: 0.0560 - val_acc: 0.9849
Epoch 14/25
60000/60000 [==============================] - 764s 13ms/step - loss: 0.0330 - acc: 0.9897 - val_l
oss: 0.0397 - val_acc: 0.9870
Epoch 15/25
60000/60000 [==============================] - 765s 13ms/step - loss: 0.0313 - acc: 0.9899 - val_l
oss: 0.0884 - val_acc: 0.9768
Epoch 16/25
60000/60000 [==============================] - 764s 13ms/step - loss: 0.0282 - acc: 0.9909 - val_l
oss: 0.0385 - val_acc: 0.9892
Epoch 17/25
60000/60000 [==============================] - 761s 13ms/step - loss: 0.0272 - acc: 0.9917 - val_l
```

```
oss: 0.0370 - val_acc: 0.9897
Epoch 18/25
60000/60000 [==============================] - 762s 13ms/step - loss: 0.0271 - acc: 0.9912 - val_l
oss: 0.0535 - val_acc: 0.9836
Epoch 19/25
60000/60000 [==============================] - 762s 13ms/step - loss: 0.0249 - acc: 0.9918 - val_l
oss: 0.0459 - val_acc: 0.9870
Epoch 20/25
60000/60000 [==============================] - 761s 13ms/step - loss: 0.0240 - acc: 0.9924 - val_l
oss: 0.0325 - val_acc: 0.9910
Epoch 21/25
60000/60000 [==============================] - 763s 13ms/step - loss: 0.0232 - acc: 0.9922 - val_l
oss: 0.0494 - val_acc: 0.9883
Epoch 22/25
60000/60000 [==============================] - 764s 13ms/step - loss: 0.0218 - acc: 0.9926 - val_l
oss: 0.0382 - val_acc: 0.9890
Epoch 23/25
60000/60000 [==============================] - 761s 13ms/step - loss: 0.0226 - acc: 0.9925 - val_l
oss: 0.0406 - val_acc: 0.9884
Epoch 24/25
60000/60000 [==============================] - 761s 13ms/step - loss: 0.0224 - acc: 0.9932 - val_l
oss: 0.0398 - val_acc: 0.9883
Epoch 25/25
60000/60000 [==============================] - 760s 13ms/step - loss: 0.0211 - acc: 0.9934 - val_l
oss: 0.0358 - val_acc: 0.9908
Test Score:  0.035796881974535066
Test Accuracy:  0.9908
```



In [0]:

```
```

1.2.2 Without Batch Normalization and Dropout

In [0]:

```
def build_model_1(input_shape, classes):
  model = Sequential()

  model.add(Convolution2D(64, (3,3), activation='sigmoid', kernel_initializer='glorot_normal', padd
ing='valid', input_shape=input_shape))
  model.add(Convolution2D(128, (3,3), activation='sigmoid', kernel_initializer='glorot_normal', pad
ding='same'))
  model.add(Convolution2D(32, (3,3), activation='sigmoid', kernel_initializer='glorot_normal', padd
ing='same'))
  model.add(MaxPooling2D(2,2))

  model.add(Flatten())
  model.add(Dense(128, activation='sigmoid', kernel_initializer='glorot_normal'))
  model.add(Dense(classes, activation='softmax'))

  return model
```

In [12]:

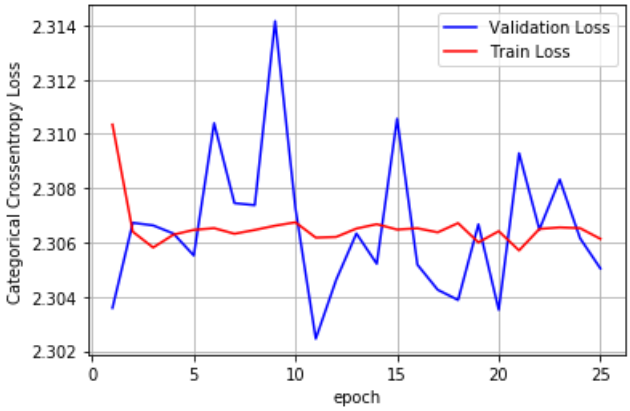
```
def run_model_1():
```

```
  batch_size = 128
  epochs = 25

  model = build_model_1(input_shape, num_classes)
  model.compile(loss=keras.losses.categorical_crossentropy,
              optimizer=keras.optimizers.Adadelta(),
              metrics=['accuracy'])

  history = model.fit(x_train, y_train,
            batch_size=batch_size,
            epochs=epochs,
            verbose=1,
            validation_data=(x_test, y_test))
  score = model.evaluate(x_test, y_test, verbose=0)
  print('Test Score: ', score[0])
  print('Test Accuracy: ', score[1])

  fig,ax = plt.subplots(1,1)
  ax.set_xlabel('epoch') ; ax.set_ylabel('Categorical Crossentropy Loss')

  # list of epoch numbers
  x = list(range(1,epochs+1))

  vy = history.history['val_loss']
  ty = history.history['loss']
  plt_dynamic(x, vy, ty, ax, fig)

run_model_1()
```

```
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:4267: The name tf.nn.max_pool is deprecated. Please u
se tf.nn.max_pool2d instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:4432: The name tf.random_uniform is deprecated. Pleas
e use tf.random.uniform instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/optimizers.py:793: The name t
f.train.Optimizer is deprecated. Please use tf.compat.v1.train.Optimizer instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:3576: The name tf.log is deprecated. Please use tf.ma
th.log instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/tensorflow_core/python/ops/math_grad.py:1424: where (from
tensorflow.python.ops.array_ops) is deprecated and will be removed in a future version.
Instructions for updating:
Use tf.where in 2.0, which has the same broadcast rule as np.where
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:1033: The name tf.assign_add is deprecated. Please us
e tf.compat.v1.assign_add instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:1020: The name tf.assign is deprecated. Please use tf
.compat.v1.assign instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:3005: The name tf.Session is deprecated. Please use t
f.compat.v1.Session instead.

Train on 60000 samples, validate on 10000 samples
Epoch 1/25
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:190: The name tf.get_default_session is deprecated. P
lease use tf.compat.v1.get_default_session instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:197: The name tf.ConfigProto is deprecated. Please us
e tf.compat.v1.ConfigProto instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:207: The name tf.global_variables is deprecated. Plea
se use tf.compat.v1.global_variables instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
```

```
packages/keras/backend/tensorflow_backend.py:216: The name tf.is_variable_initialized is
deprecated. Please use tf.compat.v1.is_variable_initialized instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:223: The name tf.variables_initializer is deprecated.
Please use tf.compat.v1.variables_initializer instead.

60000/60000 [==============================] - 814s 14ms/step - loss: 2.3103 - acc: 0.1044 - val_l
oss: 2.3036 - val_acc: 0.1135
Epoch 2/25
60000/60000 [==============================] - 858s 14ms/step - loss: 2.3064 - acc: 0.1050 - val_l
oss: 2.3067 - val_acc: 0.1009
Epoch 3/25
60000/60000 [==============================] - 838s 14ms/step - loss: 2.3058 - acc: 0.1061 - val_l
oss: 2.3066 - val_acc: 0.1028
Epoch 4/25
60000/60000 [==============================] - 835s 14ms/step - loss: 2.3063 - acc: 0.1054 - val_l
oss: 2.3063 - val_acc: 0.1135
Epoch 5/25
60000/60000 [==============================] - 826s 14ms/step - loss: 2.3065 - acc: 0.1058 - val_l
oss: 2.3055 - val_acc: 0.1010
Epoch 6/25
60000/60000 [==============================] - 819s 14ms/step - loss: 2.3065 - acc: 0.1051 - val_l
oss: 2.3104 - val_acc: 0.0980
Epoch 7/25
60000/60000 [==============================] - 812s 14ms/step - loss: 2.3063 - acc: 0.1046 - val_l
oss: 2.3075 - val_acc: 0.0974
Epoch 8/25
60000/60000 [==============================] - 813s 14ms/step - loss: 2.3065 - acc: 0.1037 - val_l
oss: 2.3074 - val_acc: 0.1028
Epoch 9/25
60000/60000 [==============================] - 844s 14ms/step - loss: 2.3066 - acc: 0.1029 - val_l
oss: 2.3142 - val_acc: 0.1010
Epoch 10/25
60000/60000 [==============================] - 841s 14ms/step - loss: 2.3067 - acc: 0.1051 - val_l
oss: 2.3073 - val_acc: 0.1009
Epoch 11/25
60000/60000 [==============================] - 852s 14ms/step - loss: 2.3062 - acc: 0.1047 - val_l
oss: 2.3025 - val_acc: 0.1135
Epoch 12/25
60000/60000 [==============================] - 851s 14ms/step - loss: 2.3062 - acc: 0.1055 - val_l
oss: 2.3046 - val_acc: 0.1009
Epoch 13/25
60000/60000 [==============================] - 848s 14ms/step - loss: 2.3065 - acc: 0.1034 - val_l
oss: 2.3063 - val_acc: 0.1009
Epoch 14/25
60000/60000 [==============================] - 848s 14ms/step - loss: 2.3067 - acc: 0.1064 - val_l
oss: 2.3052 - val_acc: 0.1032
Epoch 15/25
60000/60000 [==============================] - 841s 14ms/step - loss: 2.3065 - acc: 0.1029 - val_l
oss: 2.3106 - val_acc: 0.0892
Epoch 16/25
60000/60000 [==============================] - 840s 14ms/step - loss: 2.3065 - acc: 0.1037 - val_l
oss: 2.3052 - val_acc: 0.0958
Epoch 17/25
60000/60000 [==============================] - 830s 14ms/step - loss: 2.3064 - acc: 0.1043 - val_l
oss: 2.3043 - val_acc: 0.1028
Epoch 18/25
60000/60000 [==============================] - 814s 14ms/step - loss: 2.3067 - acc: 0.1036 - val_l
oss: 2.3039 - val_acc: 0.1028
Epoch 19/25
60000/60000 [==============================] - 818s 14ms/step - loss: 2.3060 - acc: 0.1060 - val_l
oss: 2.3067 - val_acc: 0.1028
Epoch 20/25
60000/60000 [==============================] - 837s 14ms/step - loss: 2.3064 - acc: 0.1048 - val_l
oss: 2.3035 - val_acc: 0.1010
Epoch 21/25
60000/60000 [==============================] - 832s 14ms/step - loss: 2.3057 - acc: 0.1082 - val_l
oss: 2.3093 - val_acc: 0.1010
Epoch 22/25
60000/60000 [==============================] - 820s 14ms/step - loss: 2.3065 - acc: 0.1043 - val_l
oss: 2.3065 - val_acc: 0.1135
Epoch 23/25
60000/60000 [==============================] - 806s 13ms/step - loss: 2.3066 - acc: 0.1038 - val_l
oss: 2.3083 - val_acc: 0.1135
Epoch 24/25
60000/60000 [==============================] - 787s 13ms/step - loss: 2.3065 - acc: 0.1034 - val_l
```

```
oss: 2.3062 - val_acc: 0.0982
Epoch 25/25
60000/60000 [==============================] - 775s 13ms/step - loss: 2.3061 - acc: 0.1056 - val_l
oss: 2.3050 - val_acc: 0.0958
Test Score:  2.305044367980957
Test Accuracy:  0.0958
```



2. CNN Architecture - 2

2.1 Activation: Relu

2.1.1 With Batch Normalization and Dropout

In [0]:

```
def build_model_BN_2(input_shape, classes):
  model = Sequential()

  model.add(Convolution2D(10, (5, 5), activation='relu', kernel_initializer='he_normal', padding='s
ame', input_shape=input_shape))
  model.add(Dropout(0.5))

  model.add(Convolution2D(20, (5, 5), activation='relu', kernel_initializer='he_normal', padding='s
ame'))
  model.add(Convolution2D(20, (5, 5), activation='relu', kernel_initializer='he_normal', padding='s
ame'))
  model.add(MaxPooling2D(pool_size=(2, 2), strides=(2, 2)))
  model.add(BatchNormalization())
  model.add(Dropout(0.5))

  model.add(Convolution2D(50, (5, 5), activation='relu', kernel_initializer='he_normal', padding='s
ame'))
  model.add(Convolution2D(50, (5, 5), activation='relu', kernel_initializer='he_normal', padding='s
ame'))
  model.add(MaxPooling2D(pool_size=(2, 2), strides=(2, 2)))
  model.add(BatchNormalization())
  model.add(Dropout(0.5))

  model.add(Flatten())
  model.add(Dense(500, activation='relu', kernel_initializer='he_normal'))
  model.add(BatchNormalization())
  model.add(Dropout(0.5))

  model.add(Dense(classes))
  model.add(Dropout(0.5))
  model.add(BatchNormalization())
  model.add(Dense(classes,activation="softmax"))

  return model
```

In [0]:

```
def run_model_BN_2():
  batch_size = 128
  epochs = 25
```

```
  epochs = 25

  model = build_model_2(input_shape, num_classes)
  model.compile(loss=keras.losses.categorical_crossentropy,
                optimizer=keras.optimizers.Adadelta(),
                metrics=['accuracy'])

  history = model.fit(x_train, y_train,
            batch_size=batch_size,
            epochs=epochs,
            verbose=1,
            validation_data=(x_test, y_test))
  score = model.evaluate(x_test, y_test, verbose=0)
  print('Test Score: ', score[0])
  print('Test Accuracy: ', score[1])

  fig,ax = plt.subplots(1,1)
  ax.set_xlabel('epoch') ; ax.set_ylabel('Categorical Crossentropy Loss')

  # list of epoch numbers
  x = list(range(1,epochs+1))

  vy = history.history['val_loss']
  ty = history.history['loss']
  plt_dynamic(x, vy, ty, ax, fig)

run_model_BN_2()
```

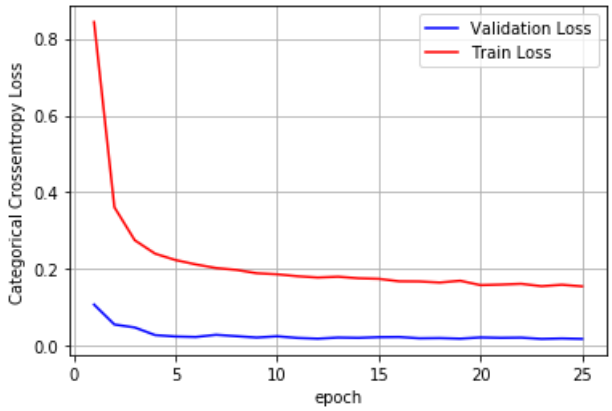
```
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:66: The name tf.get_default_graph is deprecated. Plea
se use tf.compat.v1.get_default_graph instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:541: The name tf.placeholder is deprecated. Please us
e tf.compat.v1.placeholder instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:4432: The name tf.random_uniform is deprecated. Pleas
e use tf.random.uniform instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:148: The name tf.placeholder_with_default is
deprecated. Please use tf.compat.v1.placeholder_with_default instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:3733: calling dropout (from
tensorflow.python.ops.nn_ops) with keep_prob is deprecated and will be removed in a future
version.
Instructions for updating:
Please use `rate` instead of `keep_prob`. Rate should be set to `rate = 1 - keep_prob`.
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:4267: The name tf.nn.max_pool is deprecated. Please u
se tf.nn.max_pool2d instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:190: The name tf.get_default_session is deprecated. P
lease use tf.compat.v1.get_default_session instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:197: The name tf.ConfigProto is deprecated. Please us
e tf.compat.v1.ConfigProto instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:203: The name tf.Session is deprecated. Please use tf
.compat.v1.Session instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:207: The name tf.global_variables is deprecated. Plea
se use tf.compat.v1.global_variables instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:216: The name tf.is_variable_initialized is
deprecated. Please use tf.compat.v1.is_variable_initialized instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:223: The name tf.variables_initializer is deprecated.
Please use tf.compat.v1.variables initializer instead.
```

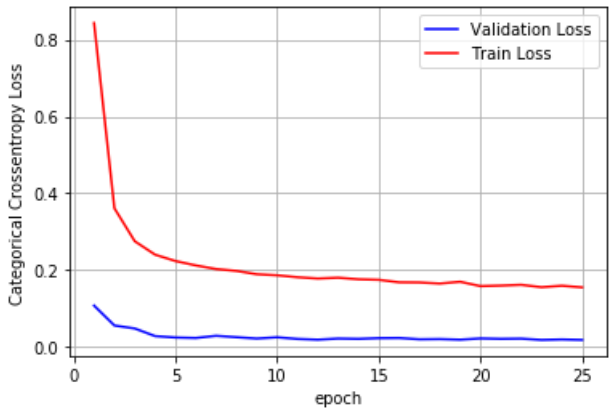
```
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:2041: The name tf.nn.fused_batch_norm is deprecated.
Please use tf.compat.v1.nn.fused_batch_norm instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/optimizers.py:793: The name t
f.train.Optimizer is deprecated. Please use tf.compat.v1.train.Optimizer instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:3576: The name tf.log is deprecated. Please use tf.ma
th.log instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/tensorflow_core/python/ops/math_grad.py:1424: where (from
tensorflow.python.ops.array_ops) is deprecated and will be removed in a future version.
Instructions for updating:
Use tf.where in 2.0, which has the same broadcast rule as np.where
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:1033: The name tf.assign_add is deprecated. Please us
e tf.compat.v1.assign_add instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:1020: The name tf.assign is deprecated. Please use tf
.compat.v1.assign instead.

Train on 60000 samples, validate on 10000 samples
Epoch 1/25
 8192/60000 [===>..........................] - ETA: 7:33 - loss: 1.5802 - acc:
0.4915WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:66: The name tf.get_default_graph is deprecated. Plea
se use tf.compat.v1.get_default_graph instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:541: The name tf.placeholder is deprecated. Please us
e tf.compat.v1.placeholder instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:4432: The name tf.random_uniform is deprecated. Pleas
e use tf.random.uniform instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:148: The name tf.placeholder_with_default is
deprecated. Please use tf.compat.v1.placeholder_with_default instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:3733: calling dropout (from
tensorflow.python.ops.nn_ops) with keep_prob is deprecated and will be removed in a future
version.
Instructions for updating:
Please use `rate` instead of `keep_prob`. Rate should be set to `rate = 1 - keep_prob`.
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:4267: The name tf.nn.max_pool is deprecated. Please u
se tf.nn.max_pool2d instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:190: The name tf.get_default_session is deprecated. P
lease use tf.compat.v1.get_default_session instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:197: The name tf.ConfigProto is deprecated. Please us
e tf.compat.v1.ConfigProto instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:203: The name tf.Session is deprecated. Please use tf
.compat.v1.Session instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:207: The name tf.global_variables is deprecated. Plea
se use tf.compat.v1.global_variables instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:216: The name tf.is_variable_initialized is
deprecated. Please use tf.compat.v1.is_variable_initialized instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:223: The name tf.variables_initializer is deprecated.
Please use tf.compat.v1.variables initializer instead.
```

```
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:2041: The name tf.nn.fused_batch_norm is deprecated.
Please use tf.compat.v1.nn.fused_batch_norm instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/optimizers.py:793: The name t
f.train.Optimizer is deprecated. Please use tf.compat.v1.train.Optimizer instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:3576: The name tf.log is deprecated. Please use tf.ma
th.log instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/tensorflow_core/python/ops/math_grad.py:1424: where (from
tensorflow.python.ops.array_ops) is deprecated and will be removed in a future version.
Instructions for updating:
Use tf.where in 2.0, which has the same broadcast rule as np.where
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:1033: The name tf.assign_add is deprecated. Please us
e tf.compat.v1.assign_add instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:1020: The name tf.assign is deprecated. Please use tf
.compat.v1.assign instead.

Train on 60000 samples, validate on 10000 samples
Epoch 1/25
60000/60000 [==============================] - 539s 9ms/step - loss: 0.8430 - acc: 0.7658 - val_lo
ss: 0.1080 - val_acc: 0.9731
60000/60000 [==============================] - 539s 9ms/step - loss: 0.8430 - acc: 0.7658 - val_lo
ss: 0.1080 - val_acc: 0.9731
Epoch 2/25
Epoch 2/25
60000/60000 [==============================] - 535s 9ms/step - loss: 0.3612 - acc: 0.8898 - val_lo
ss: 0.0562 - val_acc: 0.9825
60000/60000 [==============================] - 535s 9ms/step - loss: 0.3612 - acc: 0.8898 - val_lo
ss: 0.0562 - val_acc: 0.9825
Epoch 3/25
Epoch 3/25
60000/60000 [==============================] - 529s 9ms/step - loss: 0.2754 - acc: 0.9026 - val_lo
ss: 0.0484 - val_acc: 0.9859
60000/60000 [==============================] - 529s 9ms/step - loss: 0.2754 - acc: 0.9026 - val_lo
ss: 0.0484 - val_acc: 0.9859
Epoch 4/25
Epoch 4/25
60000/60000 [==============================] - 529s 9ms/step - loss: 0.2404 - acc: 0.9105 - val_lo
ss: 0.0286 - val_acc: 0.9908
60000/60000 [==============================] - 529s 9ms/step - loss: 0.2404 - acc: 0.9105 - val_lo
ss: 0.0286 - val_acc: 0.9908
Epoch 5/25
Epoch 5/25
60000/60000 [==============================] - 530s 9ms/step - loss: 0.2239 - acc: 0.9166 - val_lo
ss: 0.0249 - val_acc: 0.9924
60000/60000 [==============================] - 530s 9ms/step - loss: 0.2239 - acc: 0.9166 - val_lo
ss: 0.0249 - val_acc: 0.9924
Epoch 6/25
Epoch 6/25
60000/60000 [==============================] - 531s 9ms/step - loss: 0.2125 - acc: 0.9194 - val_lo
ss: 0.0237 - val_acc: 0.9942
60000/60000 [==============================] - 531s 9ms/step - loss: 0.2125 - acc: 0.9194 - val_lo
ss: 0.0237 - val_acc: 0.9942
Epoch 7/25
Epoch 7/25
60000/60000 [==============================] - 529s 9ms/step - loss: 0.2031 - acc: 0.9233 - val_lo
ss: 0.0294 - val_acc: 0.9913
60000/60000 [==============================] - 529s 9ms/step - loss: 0.2031 - acc: 0.9233 - val_lo
ss: 0.0294 - val_acc: 0.9913
Epoch 8/25
Epoch 8/25
60000/60000 [==============================] - 527s 9ms/step - loss: 0.1981 - acc: 0.9257 - val_lo
ss: 0.0257 - val_acc: 0.9935
60000/60000 [==============================] - 527s 9ms/step - loss: 0.1981 - acc: 0.9257 - val_lo
ss: 0.0257 - val_acc: 0.9935
Epoch 9/25
Epoch 9/25
60000/60000 [==============================] - 527s 9ms/step - loss: 0.1895 - acc: 0.9307 - val_lo
ss: 0.0223 - val acc: 0.9934
```

60000/60000 [==============================] - 527s 9ms/step - loss: 0.1895 - acc: 0.9307 - val_lo
ss: 0.0223 - val_acc: 0.9934
Epoch 10/25
Epoch 10/25
60000/60000 [==============================] - 528s 9ms/step - loss: 0.1868 - acc: 0.9310 - val_lo
ss: 0.0255 - val_acc: 0.9941
60000/60000 [==============================] - 528s 9ms/step - loss: 0.1868 - acc: 0.9310 - val_lo
ss: 0.0255 - val_acc: 0.9941
Epoch 11/25
Epoch 11/25
60000/60000 [==============================] - 527s 9ms/step - loss: 0.1818 - acc: 0.9330 - val_lo
ss: 0.0212 - val_acc: 0.9936
60000/60000 [==============================] - 527s 9ms/step - loss: 0.1818 - acc: 0.9330 - val_lo
ss: 0.0212 - val_acc: 0.9936
Epoch 12/25
Epoch 12/25
60000/60000 [==============================] - 526s 9ms/step - loss: 0.1784 - acc: 0.9339 - val_lo
ss: 0.0193 - val_acc: 0.9943
60000/60000 [==============================] - 526s 9ms/step - loss: 0.1784 - acc: 0.9339 - val_lo
ss: 0.0193 - val_acc: 0.9943
Epoch 13/25
Epoch 13/25
60000/60000 [==============================] - 529s 9ms/step - loss: 0.1805 - acc: 0.9329 - val_lo
ss: 0.0222 - val_acc: 0.9945
60000/60000 [==============================] - 529s 9ms/step - loss: 0.1805 - acc: 0.9329 - val_lo
ss: 0.0222 - val_acc: 0.9945
Epoch 14/25
Epoch 14/25
60000/60000 [==============================] - 529s 9ms/step - loss: 0.1764 - acc: 0.9352 - val_lo
ss: 0.0214 - val_acc: 0.9947
60000/60000 [==============================] - 529s 9ms/step - loss: 0.1764 - acc: 0.9352 - val_lo
ss: 0.0214 - val_acc: 0.9947
Epoch 15/25
Epoch 15/25
60000/60000 [==============================] - 529s 9ms/step - loss: 0.1750 - acc: 0.9365 - val_lo
ss: 0.0233 - val_acc: 0.9939
60000/60000 [==============================] - 529s 9ms/step - loss: 0.1750 - acc: 0.9365 - val_lo
ss: 0.0233 - val_acc: 0.9939
Epoch 16/25
Epoch 16/25
60000/60000 [==============================] - 528s 9ms/step - loss: 0.1685 - acc: 0.9380 - val_lo
ss: 0.0237 - val_acc: 0.9946
60000/60000 [==============================] - 528s 9ms/step - loss: 0.1685 - acc: 0.9380 - val_lo
ss: 0.0237 - val_acc: 0.9946
Epoch 17/25
Epoch 17/25
60000/60000 [==============================] - 538s 9ms/step - loss: 0.1681 - acc: 0.9381 - val_lo
ss: 0.0202 - val_acc: 0.9949
60000/60000 [==============================] - 538s 9ms/step - loss: 0.1681 - acc: 0.9381 - val_lo
ss: 0.0202 - val_acc: 0.9949
Epoch 18/25
Epoch 18/25
60000/60000 [==============================] - 541s 9ms/step - loss: 0.1653 - acc: 0.9375 - val_lo
ss: 0.0208 - val_acc: 0.9942
60000/60000 [==============================] - 541s 9ms/step - loss: 0.1653 - acc: 0.9375 - val_lo
ss: 0.0208 - val_acc: 0.9942
Epoch 19/25
Epoch 19/25
60000/60000 [==============================] - 539s 9ms/step - loss: 0.1700 - acc: 0.9381 - val_lo
ss: 0.0193 - val_acc: 0.9950
60000/60000 [==============================] - 539s 9ms/step - loss: 0.1700 - acc: 0.9381 - val_lo
ss: 0.0193 - val_acc: 0.9950
Epoch 20/25
Epoch 20/25
60000/60000 [==============================] - 539s 9ms/step - loss: 0.1586 - acc: 0.9423 - val_lo
ss: 0.0225 - val_acc: 0.9945
60000/60000 [==============================] - 539s 9ms/step - loss: 0.1586 - acc: 0.9423 - val_lo
ss: 0.0225 - val_acc: 0.9945
Epoch 21/25
Epoch 21/25
60000/60000 [==============================] - 537s 9ms/step - loss: 0.1600 - acc: 0.9413 - val_lo
ss: 0.0214 - val_acc: 0.9956
60000/60000 [==============================] - 537s 9ms/step - loss: 0.1600 - acc: 0.9413 - val_lo
ss: 0.0214 - val_acc: 0.9956
Epoch 22/25
Epoch 22/25
60000/60000 [==============================] - 538s 9ms/step - loss: 0.1621 - acc: 0.9409 - val_lo

```
ss: 0.0220 - val_acc: 0.9950
60000/60000 [==============================] - 538s 9ms/step - loss: 0.1621 - acc: 0.9409 - val_lo
ss: 0.0220 - val_acc: 0.9950
Epoch 23/25
Epoch 23/25
60000/60000 [==============================] - 540s 9ms/step - loss: 0.1558 - acc: 0.9418 - val_lo
ss: 0.0187 - val_acc: 0.9957
60000/60000 [==============================] - 540s 9ms/step - loss: 0.1558 - acc: 0.9418 - val_lo
ss: 0.0187 - val_acc: 0.9957
Epoch 24/25
Epoch 24/25
60000/60000 [==============================] - 537s 9ms/step - loss: 0.1596 - acc: 0.9415 - val_lo
ss: 0.0199 - val_acc: 0.9953
60000/60000 [==============================] - 537s 9ms/step - loss: 0.1596 - acc: 0.9415 - val_lo
ss: 0.0199 - val_acc: 0.9953
Epoch 25/25
Epoch 25/25
60000/60000 [==============================] - 538s 9ms/step - loss: 0.1554 - acc: 0.9436 - val_lo
ss: 0.0187 - val_acc: 0.9958
60000/60000 [==============================] - 538s 9ms/step - loss: 0.1554 - acc: 0.9436 - val_lo
ss: 0.0187 - val_acc: 0.9958
Test Score:  0.018711723503737 81
Test Accuracy:  0.9958
Test Score:  0.018711723503737 81
Test Accuracy:  0.9958
```





In [0]:

```
```

2.1.2 Without Batch Normalization and Dropout

In [0]:

```
def build_model_2(input_shape, classes):
  model = Sequential()

  model.add(Convolution2D(10, (5, 5), activation='relu', kernel_initializer='he_normal', padding='s
ame', input_shape=input_shape))
```

```
  model.add(Convolution2D(20, (5, 5), activation='relu', kernel_initializer='he_normal', padding='same'))
  model.add(Convolution2D(20, (5, 5), activation='relu', kernel_initializer='he_normal', padding='same'))
  model.add(MaxPooling2D(pool_size=(2, 2), strides=(2, 2)))

  model.add(Convolution2D(50, (5, 5), activation='relu', kernel_initializer='he_normal', padding='same'))
  model.add(Convolution2D(50, (5, 5), activation='relu', kernel_initializer='he_normal', padding='same'))
  model.add(MaxPooling2D(pool_size=(2, 2), strides=(2, 2)))

  model.add(Flatten())
  model.add(Dense(500, activation='relu', kernel_initializer='he_normal'))

  model.add(Dense(classes))

  model.add(Dense(classes,activation="softmax"))

  return model
```

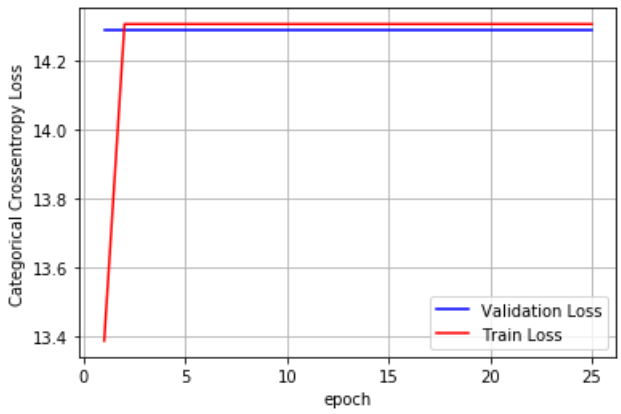
In [0]:

```
def run_model_2():
  batch_size = 128
  epochs = 25

  model = build_model_2(input_shape, num_classes)
  model.compile(loss=keras.losses.categorical_crossentropy,
              optimizer=keras.optimizers.Adadelta(),
              metrics=['accuracy'])

  history = model.fit(x_train, y_train,
            batch_size=batch_size,
            epochs=epochs,
            verbose=1,
            validation_data=(x_test, y_test))
  score = model.evaluate(x_test, y_test, verbose=0)
  print('Test Score: ', score[0])
  print('Test Accuracy: ', score[1])

  fig,ax = plt.subplots(1,1)
  ax.set_xlabel('epoch') ; ax.set_ylabel('Categorical Crossentropy Loss')

  # list of epoch numbers
  x = list(range(1,epochs+1))

  vy = history.history['val_loss']
  ty = history.history['loss']
  plt_dynamic(x, vy, ty, ax, fig)

run_model_2()
```

```
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/backend/tensorflow_backend.py:66: The name tf.get_default_graph is deprecated. Please use tf.compat.v1.get_default_graph instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/backend/tensorflow_backend.py:541: The name tf.placeholder is deprecated. Please use tf.compat.v1.placeholder instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/backend/tensorflow_backend.py:4432: The name tf.random_uniform is deprecated. Please use tf.random.uniform instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/backend/tensorflow_backend.py:4267: The name tf.nn.max_pool is deprecated. Please use tf.nn.max_pool2d instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/optimizers.py:793: The name tf.train.Optimizer is deprecated. Please use tf.compat.v1.train.Optimizer instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/backend/tensorflow_backend.py:3576: The name tf.log is deprecated. Please use tf.math.log instead.
```

```
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/tensorflow_core/python/ops/math_grad.py:1424: where (from
tensorflow.python.ops.array_ops) is deprecated and will be removed in a future version.
Instructions for updating:
Use tf.where in 2.0, which has the same broadcast rule as np.where
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:1033: The name tf.assign_add is deprecated. Please us
e tf.compat.v1.assign_add instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:1020: The name tf.assign is deprecated. Please use tf
.compat.v1.assign instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:3005: The name tf.Session is deprecated. Please use t
f.compat.v1.Session instead.

Train on 60000 samples, validate on 10000 samples
Epoch 1/25
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:190: The name tf.get_default_session is deprecated. P
lease use tf.compat.v1.get_default_session instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:197: The name tf.ConfigProto is deprecated. Please us
e tf.compat.v1.ConfigProto instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:207: The name tf.global_variables is deprecated. Plea
se use tf.compat.v1.global_variables instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:216: The name tf.is_variable_initialized is
deprecated. Please use tf.compat.v1.is_variable_initialized instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:223: The name tf.variables_initializer is deprecated.
Please use tf.compat.v1.variables_initializer instead.

60000/60000 [==============================] - 492s 8ms/step - loss: 13.3868 - acc: 0.1328 - val_l
oss: 14.2887 - val_acc: 0.1135
Epoch 2/25
60000/60000 [==============================] - 488s 8ms/step - loss: 14.3070 - acc: 0.1124 - val_l
oss: 14.2887 - val_acc: 0.1135
Epoch 3/25
60000/60000 [==============================] - 485s 8ms/step - loss: 14.3070 - acc: 0.1124 - val_l
oss: 14.2887 - val_acc: 0.1135
Epoch 4/25
60000/60000 [==============================] - 486s 8ms/step - loss: 14.3070 - acc: 0.1124 - val_l
oss: 14.2887 - val_acc: 0.1135
Epoch 5/25
60000/60000 [==============================] - 485s 8ms/step - loss: 14.3070 - acc: 0.1124 - val_l
oss: 14.2887 - val_acc: 0.1135
Epoch 6/25
60000/60000 [==============================] - 485s 8ms/step - loss: 14.3070 - acc: 0.1124 - val_l
oss: 14.2887 - val_acc: 0.1135
Epoch 7/25
60000/60000 [==============================] - 485s 8ms/step - loss: 14.3070 - acc: 0.1124 - val_l
oss: 14.2887 - val_acc: 0.1135
Epoch 8/25
60000/60000 [==============================] - 484s 8ms/step - loss: 14.3070 - acc: 0.1124 - val_l
oss: 14.2887 - val_acc: 0.1135
Epoch 9/25
60000/60000 [==============================] - 482s 8ms/step - loss: 14.3070 - acc: 0.1124 - val_l
oss: 14.2887 - val_acc: 0.1135
Epoch 10/25
60000/60000 [==============================] - 483s 8ms/step - loss: 14.3070 - acc: 0.1124 - val_l
oss: 14.2887 - val_acc: 0.1135
Epoch 11/25
60000/60000 [==============================] - 482s 8ms/step - loss: 14.3070 - acc: 0.1124 - val_l
oss: 14.2887 - val_acc: 0.1135
Epoch 12/25
60000/60000 [==============================] - 483s 8ms/step - loss: 14.3070 - acc: 0.1124 - val_l
oss: 14.2887 - val_acc: 0.1135
Epoch 13/25
60000/60000 [==============================] - 488s 8ms/step - loss: 14.3070 - acc: 0.1124 - val_l
```

```
oss: 14.2887 - val_acc: 0.1135
Epoch 14/25
60000/60000 [==============================] - 486s 8ms/step - loss: 14.3070 - acc: 0.1124 - val_l
oss: 14.2887 - val_acc: 0.1135
Epoch 15/25
60000/60000 [==============================] - 488s 8ms/step - loss: 14.3070 - acc: 0.1124 - val_l
oss: 14.2887 - val_acc: 0.1135
Epoch 16/25
60000/60000 [==============================] - 486s 8ms/step - loss: 14.3070 - acc: 0.1124 - val_l
oss: 14.2887 - val_acc: 0.1135
Epoch 17/25
60000/60000 [==============================] - 487s 8ms/step - loss: 14.3070 - acc: 0.1124 - val_l
oss: 14.2887 - val_acc: 0.1135
Epoch 18/25
60000/60000 [==============================] - 488s 8ms/step - loss: 14.3070 - acc: 0.1124 - val_l
oss: 14.2887 - val_acc: 0.1135
Epoch 19/25
60000/60000 [==============================] - 488s 8ms/step - loss: 14.3070 - acc: 0.1124 - val_l
oss: 14.2887 - val_acc: 0.1135
Epoch 20/25
60000/60000 [==============================] - 490s 8ms/step - loss: 14.3070 - acc: 0.1124 - val_l
oss: 14.2887 - val_acc: 0.1135
Epoch 21/25
60000/60000 [==============================] - 490s 8ms/step - loss: 14.3070 - acc: 0.1124 - val_l
oss: 14.2887 - val_acc: 0.1135
Epoch 22/25
60000/60000 [==============================] - 490s 8ms/step - loss: 14.3070 - acc: 0.1124 - val_l
oss: 14.2887 - val_acc: 0.1135
Epoch 23/25
60000/60000 [==============================] - 489s 8ms/step - loss: 14.3070 - acc: 0.1124 - val_l
oss: 14.2887 - val_acc: 0.1135
Epoch 24/25
60000/60000 [==============================] - 489s 8ms/step - loss: 14.3070 - acc: 0.1124 - val_l
oss: 14.2887 - val_acc: 0.1135
Epoch 25/25
60000/60000 [==============================] - 490s 8ms/step - loss: 14.3070 - acc: 0.1124 - val_l
oss: 14.2887 - val_acc: 0.1135
Test Score:  14.28869146270752
Test Accuracy:  0.1135
```



In [0]:

```
```

2.2 Activation: Sigmoid

2.2.1 With Batch Normalization and Dropout

In [0]:

```
def build_model_BN_2(input_shape, classes):
  model = Sequential()

  model.add(Convolution2D(10, (5, 5), activation='sigmoid', kernel_initializer='glorot_normal', pad
ding='same', input_shape=input_shape))
  model.add(Dropout(0.5))
```

```
  model.add(Convolution2D(20, (5, 5), activation='sigmoid', kernel_initializer='glorot_normal', pad
ding='same'))
  model.add(Convolution2D(20, (5, 5), activation='sigmoid', kernel_initializer='glorot_normal', pad
ding='same'))
  model.add(MaxPooling2D(pool_size=(2, 2), strides=(2, 2)))
  model.add(BatchNormalization())
  model.add(Dropout(0.5))

  model.add(Convolution2D(50, (5, 5), activation='sigmoid', kernel_initializer='glorot_normal', pad
ding='same'))
  model.add(Convolution2D(50, (5, 5), activation='sigmoid', kernel_initializer='glorot_normal', pad
ding='same'))
  model.add(MaxPooling2D(pool_size=(2, 2), strides=(2, 2)))
  model.add(BatchNormalization())
  model.add(Dropout(0.5))

  model.add(Flatten())
  model.add(Dense(500, activation='sigmoid', kernel_initializer='glorot_normal'))
  model.add(BatchNormalization())
  model.add(Dropout(0.5))

  model.add(Dense(classes))
  model.add(Dropout(0.5))
  model.add(BatchNormalization())
  model.add(Dense(classes,activation="softmax"))

  return model
```

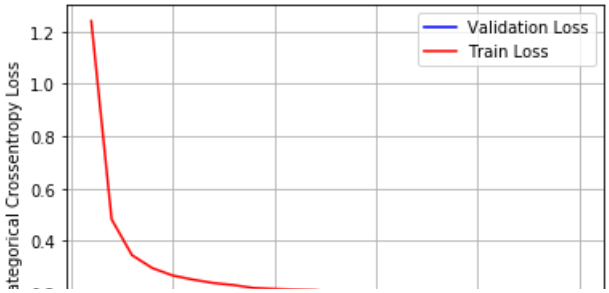
In [7]:

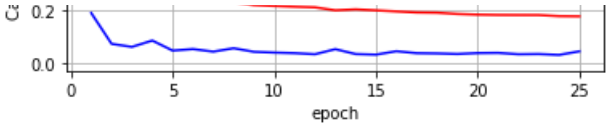
```
def run_model_BN_2():
  batch_size = 128
  epochs = 25

  model = build_model_BN_2(input_shape, num_classes)
  model.compile(loss=keras.losses.categorical_crossentropy,
              optimizer=keras.optimizers.Adadelta(),
              metrics=['accuracy'])

  history = model.fit(x_train, y_train,
            batch_size=batch_size,
            epochs=epochs,
            verbose=1,
            validation_data=(x_test, y_test))
  score = model.evaluate(x_test, y_test, verbose=0)
  print('Test Score: ', score[0])
  print('Test Accuracy: ', score[1])

  fig,ax = plt.subplots(1,1)
  ax.set_xlabel('epoch') ; ax.set_ylabel('Categorical Crossentropy Loss')

  # list of epoch numbers
  x = list(range(1,epochs+1))

  vy = history.history['val_loss']
  ty = history.history['loss']
  plt_dynamic(x, vy, ty, ax, fig)

run_model_BN_2()
```

```
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:66: The name tf.get_default_graph is deprecated. Plea
se use tf.compat.v1.get_default_graph instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:541: The name tf.placeholder is deprecated. Please us
e tf.compat.v1.placeholder instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:4479: The name tf.truncated_normal is deprecated. Ple
ase use tf.random.truncated_normal instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:148: The name tf.placeholder_with_default is
deprecated. Please use tf.compat.v1.placeholder_with_default instead.
```

```
deprecated. Please use tf.compat.v1.placeholder_with_default instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:3733: calling dropout (from
tensorflow.python.ops.nn_ops) with keep_prob is deprecated and will be removed in a future
version.
Instructions for updating:
Please use `rate` instead of `keep_prob`. Rate should be set to `rate = 1 - keep_prob`.
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:4267: The name tf.nn.max_pool is deprecated. Please u
se tf.nn.max_pool2d instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:190: The name tf.get_default_session is deprecated. P
lease use tf.compat.v1.get_default_session instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:197: The name tf.ConfigProto is deprecated. Please us
e tf.compat.v1.ConfigProto instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:203: The name tf.Session is deprecated. Please use tf
.compat.v1.Session instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:207: The name tf.global_variables is deprecated. Plea
se use tf.compat.v1.global_variables instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:216: The name tf.is_variable_initialized is
deprecated. Please use tf.compat.v1.is_variable_initialized instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:223: The name tf.variables_initializer is deprecated.
Please use tf.compat.v1.variables_initializer instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:2041: The name tf.nn.fused_batch_norm is deprecated.
Please use tf.compat.v1.nn.fused_batch_norm instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:4432: The name tf.random_uniform is deprecated. Pleas
e use tf.random.uniform instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/optimizers.py:793: The name t
f.train.Optimizer is deprecated. Please use tf.compat.v1.train.Optimizer instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:3576: The name tf.log is deprecated. Please use tf.ma
th.log instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/tensorflow_core/python/ops/math_grad.py:1424: where (from
tensorflow.python.ops.array_ops) is deprecated and will be removed in a future version.
Instructions for updating:
Use tf.where in 2.0, which has the same broadcast rule as np.where
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:1033: The name tf.assign_add is deprecated. Please us
e tf.compat.v1.assign_add instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:1020: The name tf.assign is deprecated. Please use tf
.compat.v1.assign instead.

Train on 60000 samples, validate on 10000 samples
Epoch 1/25
60000/60000 [==============================] - 510s 9ms/step - loss: 1.2401 - acc: 0.6203 - val_lo
ss: 0.1894 - val_acc: 0.9513
Epoch 2/25
60000/60000 [==============================] - 507s 8ms/step - loss: 0.4826 - acc: 0.8535 - val_lo
ss: 0.0718 - val_acc: 0.9791
Epoch 3/25
60000/60000 [==============================] - 507s 8ms/step - loss: 0.3458 - acc: 0.8837 - val_lo
ss: 0.0603 - val_acc: 0.9819
Epoch 4/25
60000/60000 [==============================] - 507s 8ms/step - loss: 0.2964 - acc: 0.8956 - val_lo
ss: 0.0845 - val_acc: 0.9725
Epoch 5/25
```

```
Epoch 5/25
60000/60000 [==============================] - 506s 8ms/step - loss: 0.2681 - acc: 0.9057 - val_lo
ss: 0.0461 - val_acc: 0.9868
Epoch 6/25
60000/60000 [==============================] - 506s 8ms/step - loss: 0.2522 - acc: 0.9115 - val_lo
ss: 0.0519 - val_acc: 0.9856
Epoch 7/25
60000/60000 [==============================] - 505s 8ms/step - loss: 0.2394 - acc: 0.9146 - val_lo
ss: 0.0422 - val_acc: 0.9905
Epoch 8/25
60000/60000 [==============================] - 505s 8ms/step - loss: 0.2315 - acc: 0.9184 - val_lo
ss: 0.0551 - val_acc: 0.9827
Epoch 9/25
60000/60000 [==============================] - 506s 8ms/step - loss: 0.2201 - acc: 0.9202 - val_lo
ss: 0.0415 - val_acc: 0.9907
Epoch 10/25
60000/60000 [==============================] - 505s 8ms/step - loss: 0.2165 - acc: 0.9227 - val_lo
ss: 0.0385 - val_acc: 0.9912
Epoch 11/25
60000/60000 [==============================] - 506s 8ms/step - loss: 0.2137 - acc: 0.9239 - val_lo
ss: 0.0363 - val_acc: 0.9922
Epoch 12/25
60000/60000 [==============================] - 506s 8ms/step - loss: 0.2114 - acc: 0.9247 - val_lo
ss: 0.0322 - val_acc: 0.9921
Epoch 13/25
60000/60000 [==============================] - 507s 8ms/step - loss: 0.2000 - acc: 0.9292 - val_lo
ss: 0.0516 - val_acc: 0.9873
Epoch 14/25
60000/60000 [==============================] - 507s 8ms/step - loss: 0.2036 - acc: 0.9269 - val_lo
ss: 0.0329 - val_acc: 0.9918
Epoch 15/25
60000/60000 [==============================] - 509s 8ms/step - loss: 0.1998 - acc: 0.9289 - val_lo
ss: 0.0307 - val_acc: 0.9928
Epoch 16/25
60000/60000 [==============================] - 508s 8ms/step - loss: 0.1957 - acc: 0.9305 - val_lo
ss: 0.0437 - val_acc: 0.9909
Epoch 17/25
60000/60000 [==============================] - 508s 8ms/step - loss: 0.1917 - acc: 0.9317 - val_lo
ss: 0.0363 - val_acc: 0.9921
Epoch 18/25
60000/60000 [==============================] - 508s 8ms/step - loss: 0.1908 - acc: 0.9317 - val_lo
ss: 0.0352 - val_acc: 0.9929
Epoch 19/25
60000/60000 [==============================] - 507s 8ms/step - loss: 0.1860 - acc: 0.9339 - val_lo
ss: 0.0331 - val_acc: 0.9933
Epoch 20/25
60000/60000 [==============================] - 508s 8ms/step - loss: 0.1834 - acc: 0.9357 - val_lo
ss: 0.0366 - val_acc: 0.9930
Epoch 21/25
60000/60000 [==============================] - 508s 8ms/step - loss: 0.1823 - acc: 0.9358 - val_lo
ss: 0.0374 - val_acc: 0.9923
Epoch 22/25
60000/60000 [==============================] - 508s 8ms/step - loss: 0.1820 - acc: 0.9355 - val_lo
ss: 0.0322 - val_acc: 0.9929
Epoch 23/25
60000/60000 [==============================] - 509s 8ms/step - loss: 0.1819 - acc: 0.9348 - val_lo
ss: 0.0329 - val_acc: 0.9930
Epoch 24/25
60000/60000 [==============================] - 509s 8ms/step - loss: 0.1777 - acc: 0.9391 - val_lo
ss: 0.0296 - val_acc: 0.9930
Epoch 25/25
60000/60000 [==============================] - 508s 8ms/step - loss: 0.1770 - acc: 0.9368 - val_lo
ss: 0.0433 - val_acc: 0.9920
Test Score:  0.043298124417303185
Test Accuracy:  0.992
```





In [0]:

```
```

2.2.2 Without Batch Normalization and Dropout

In [0]:

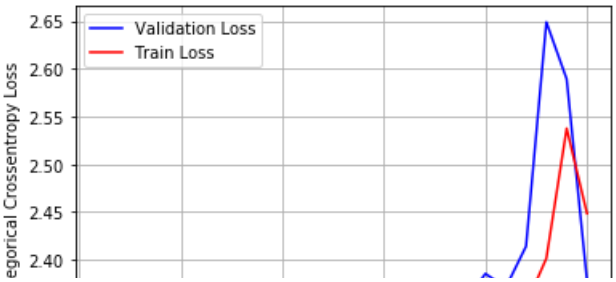
```
def build_model_2(input_shape, classes):
  model = Sequential()

  model.add(Convolution2D(10, (5, 5), activation='sigmoid', kernel_initializer='glorot_normal', pad
ding='same', input_shape=input_shape))

  model.add(Convolution2D(20, (5, 5), activation='sigmoid', kernel_initializer='glorot_normal', pad
ding='same'))
  model.add(Convolution2D(20, (5, 5), activation='sigmoid', kernel_initializer='glorot_normal', pad
ding='same'))
  model.add(MaxPooling2D(pool_size=(2, 2), strides=(2, 2)))

  model.add(Convolution2D(50, (5, 5), activation='sigmoid', kernel_initializer='glorot_normal', pad
ding='same'))
  model.add(Convolution2D(50, (5, 5), activation='sigmoid', kernel_initializer='glorot_normal', pad
ding='same'))
  model.add(MaxPooling2D(pool_size=(2, 2), strides=(2, 2)))

  model.add(Flatten())
  model.add(Dense(500, activation='sigmoid', kernel_initializer='glorot_normal'))

  model.add(Dense(classes))

  model.add(Dense(classes,activation="softmax"))

  return model
```

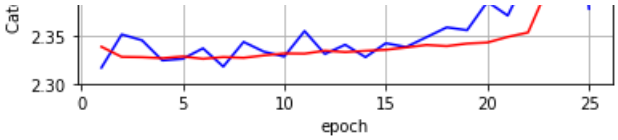
In [6]:

```
def run_model_2():
  batch_size = 128
  epochs = 25

  model = build_model_2(input_shape, num_classes)
  model.compile(loss=keras.losses.categorical_crossentropy,
                optimizer=keras.optimizers.Adadelta(),
                metrics=['accuracy'])

  history = model.fit(x_train, y_train,
            batch_size=batch_size,
            epochs=epochs,
            verbose=1,
            validation_data=(x_test, y_test))
  score = model.evaluate(x_test, y_test, verbose=0)
  print('Test Score: ', score[0])
  print('Test Accuracy: ', score[1])

  fig,ax = plt.subplots(1,1)
  ax.set_xlabel('epoch') ; ax.set_ylabel('Categorical Crossentropy Loss')

  # list of epoch numbers
  x = list(range(1,epochs+1))

  vy = history.history['val_loss']
  ty = history.history['loss']
  plt_dynamic(x, vy, ty, ax, fig)

run_model_2()
```

```
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:66: The name tf.get_default_graph is deprecated. Plea
se use tf.compat.v1.get_default_graph instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:541: The name tf.placeholder is deprecated. Please us
e tf.compat.v1.placeholder instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:4479: The name tf.truncated_normal is deprecated. Ple
ase use tf.random.truncated_normal instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:4267: The name tf.nn.max_pool is deprecated. Please u
se tf.nn.max_pool2d instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:4432: The name tf.random_uniform is deprecated. Pleas
e use tf.random.uniform instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/optimizers.py:793: The name t
f.train.Optimizer is deprecated. Please use tf.compat.v1.train.Optimizer instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:3576: The name tf.log is deprecated. Please use tf.ma
th.log instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/tensorflow_core/python/ops/math_grad.py:1424: where (from
tensorflow.python.ops.array_ops) is deprecated and will be removed in a future version.
Instructions for updating:
Use tf.where in 2.0, which has the same broadcast rule as np.where
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:1033: The name tf.assign_add is deprecated. Please us
e tf.compat.v1.assign_add instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:1020: The name tf.assign is deprecated. Please use tf
.compat.v1.assign instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:3005: The name tf.Session is deprecated. Please use t
f.compat.v1.Session instead.

Train on 60000 samples, validate on 10000 samples
Epoch 1/25
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:190: The name tf.get_default_session is deprecated. P
lease use tf.compat.v1.get_default_session instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:197: The name tf.ConfigProto is deprecated. Please us
e tf.compat.v1.ConfigProto instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:207: The name tf.global_variables is deprecated. Plea
se use tf.compat.v1.global_variables instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:216: The name tf.is_variable_initialized is
deprecated. Please use tf.compat.v1.is_variable_initialized instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:223: The name tf.variables_initializer is deprecated.
Please use tf.compat.v1.variables_initializer instead.

60000/60000 [==============================] - 514s 9ms/step - loss: 2.3384 - acc: 0.1014 - val_lo
ss: 2.3164 - val_acc: 0.1032
Epoch 2/25
60000/60000 [==============================] - 512s 9ms/step - loss: 2.3277 - acc: 0.1013 - val_lo
ss: 2.3513 - val_acc: 0.1028
Epoch 3/25
60000/60000 [==============================] - 513s 9ms/step - loss: 2.3274 - acc: 0.1031 - val_lo
ss: 2.3451 - val_acc: 0.1009
Epoch 4/25
60000/60000 [==============================] - 513s 9ms/step - loss: 2.3264 - acc: 0.1036 - val_lo
ss: 2.3240 - val_acc: 0.1028
```

```
Epoch 5/25
60000/60000 [==============================] - 511s 9ms/step - loss: 2.3282 - acc: 0.1013 - val_lo
ss: 2.3257 - val_acc: 0.0958
Epoch 6/25
60000/60000 [==============================] - 512s 9ms/step - loss: 2.3257 - acc: 0.1030 - val_lo
ss: 2.3367 - val_acc: 0.1010
Epoch 7/25
60000/60000 [==============================] - 514s 9ms/step - loss: 2.3276 - acc: 0.1016 - val_lo
ss: 2.3176 - val_acc: 0.1032
Epoch 8/25
60000/60000 [==============================] - 513s 9ms/step - loss: 2.3268 - acc: 0.1042 - val_lo
ss: 2.3434 - val_acc: 0.1135
Epoch 9/25
60000/60000 [==============================] - 512s 9ms/step - loss: 2.3293 - acc: 0.1012 - val_lo
ss: 2.3332 - val_acc: 0.0974
Epoch 10/25
60000/60000 [==============================] - 512s 9ms/step - loss: 2.3314 - acc: 0.1012 - val_lo
ss: 2.3281 - val_acc: 0.0958
Epoch 11/25
60000/60000 [==============================] - 514s 9ms/step - loss: 2.3311 - acc: 0.1027 - val_lo
ss: 2.3548 - val_acc: 0.1032
Epoch 12/25
60000/60000 [==============================] - 517s 9ms/step - loss: 2.3342 - acc: 0.0998 - val_lo
ss: 2.3307 - val_acc: 0.0958
Epoch 13/25
60000/60000 [==============================] - 517s 9ms/step - loss: 2.3328 - acc: 0.1050 - val_lo
ss: 2.3405 - val_acc: 0.1135
Epoch 14/25
60000/60000 [==============================] - 516s 9ms/step - loss: 2.3341 - acc: 0.1006 - val_lo
ss: 2.3274 - val_acc: 0.1028
Epoch 15/25
60000/60000 [==============================] - 516s 9ms/step - loss: 2.3352 - acc: 0.1043 - val_lo
ss: 2.3421 - val_acc: 0.1009
Epoch 16/25
60000/60000 [==============================] - 515s 9ms/step - loss: 2.3376 - acc: 0.1015 - val_lo
ss: 2.3381 - val_acc: 0.1135
Epoch 17/25
60000/60000 [==============================] - 516s 9ms/step - loss: 2.3402 - acc: 0.1020 - val_lo
ss: 2.3484 - val_acc: 0.1028
Epoch 18/25
60000/60000 [==============================] - 517s 9ms/step - loss: 2.3390 - acc: 0.1031 - val_lo
ss: 2.3587 - val_acc: 0.1032
Epoch 19/25
60000/60000 [==============================] - 515s 9ms/step - loss: 2.3417 - acc: 0.1012 - val_lo
ss: 2.3557 - val_acc: 0.1135
Epoch 20/25
60000/60000 [==============================] - 517s 9ms/step - loss: 2.3428 - acc: 0.1010 - val_lo
ss: 2.3855 - val_acc: 0.0974
Epoch 21/25
60000/60000 [==============================] - 518s 9ms/step - loss: 2.3487 - acc: 0.1003 - val_lo
ss: 2.3709 - val_acc: 0.1028
Epoch 22/25
60000/60000 [==============================] - 517s 9ms/step - loss: 2.3533 - acc: 0.1032 - val_lo
ss: 2.4142 - val_acc: 0.0982
Epoch 23/25
60000/60000 [==============================] - 517s 9ms/step - loss: 2.4016 - acc: 0.1015 - val_lo
ss: 2.6488 - val_acc: 0.0958
Epoch 24/25
60000/60000 [==============================] - 517s 9ms/step - loss: 2.5376 - acc: 0.1007 - val_lo
ss: 2.5892 - val_acc: 0.1135
Epoch 25/25
60000/60000 [==============================] - 517s 9ms/step - loss: 2.4486 - acc: 0.1024 - val_lo
ss: 2.3781 - val_acc: 0.1010
Test Score:  2.378144398880005
Test Accuracy:  0.101
```





3. CNN Architecture - 3

3.1 Activation: Relu

3.1.1 With Batch Normalisation and Dropouts

In [0]:

```
def build_model_BN_3(input_shape, classes):
  model = Sequential()

  model = Sequential()

  model.add(Convolution2D(100, (2, 2), activation='relu', kernel_initializer='he_normal', padding='
same', input_shape=input_shape))
  model.add(Dropout(0.25))

  model.add(Convolution2D(80, (2, 2), activation='relu', kernel_initializer='he_normal', padding='s
ame'))
  model.add(Convolution2D(80, (2, 2), activation='relu', kernel_initializer='he_normal', padding='s
ame'))
  model.add(MaxPooling2D(pool_size=(3, 3)))
  model.add(BatchNormalization())
  model.add(Dropout(0.25))

  model.add(Convolution2D(60, (2, 2), activation='relu', kernel_initializer='he_normal', padding='s
ame'))
  model.add(Convolution2D(60, (2, 2), activation='relu', kernel_initializer='he_normal', padding='s
ame'))
  model.add(MaxPooling2D(pool_size=(3, 3)))
  model.add(BatchNormalization())
  model.add(Dropout(0.25))

  model.add(Convolution2D(40, (2, 2), activation='relu', kernel_initializer='he_normal', padding='s
ame'))
  model.add(Convolution2D(40, (2, 2), activation='relu', kernel_initializer='he_normal', padding='s
ame'))
  model.add(MaxPooling2D(pool_size=(3, 3)))
  model.add(BatchNormalization())
  model.add(Dropout(0.25))

  model.add(Flatten())
  model.add(Dense(300, activation='relu', kernel_initializer='he_normal'))
  model.add(BatchNormalization())
  model.add(Dropout(0.5))

  model.add(Dense(classes))
  model.add(BatchNormalization())
  model.add(Dropout(0.5))
  model.add(Dense(classes,activation="softmax"))

  return model
```

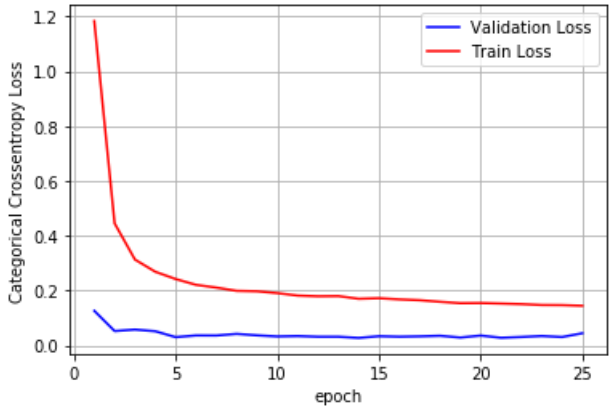
In [0]:

```
def run_model_BN_3():
  batch_size = 128
  epochs = 25

  model = build_model_BN_3(input_shape, num_classes)
  model.compile(loss=keras.losses.categorical_crossentropy,
                optimizer=keras.optimizers.Adadelta(),
                metrics=['accuracy'])

  history = model.fit(x_train, y_train,
```

```
            batch_size=batch_size,
            epochs=epochs,
            verbose=1,

            validation_data=(x_test, y_test))
  score = model.evaluate(x_test, y_test, verbose=0)
  print('Test Score: ', score[0])
  print('Test Accuracy: ', score[1])

  fig,ax = plt.subplots(1,1)
  ax.set_xlabel('epoch') ; ax.set_ylabel('Categorical Crossentropy Loss')

  # list of epoch numbers
  x = list(range(1,epochs+1))

  vy = history.history['val_loss']
  ty = history.history['loss']
  plt_dynamic(x, vy, ty, ax, fig)

run_model_BN_3()
```

```
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:148: The name tf.placeholder_with_default is
deprecated. Please use tf.compat.v1.placeholder_with_default instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:3733: calling dropout (from
tensorflow.python.ops.nn_ops) with keep_prob is deprecated and will be removed in a future
version.
Instructions for updating:
Please use `rate` instead of `keep_prob`. Rate should be set to `rate = 1 - keep_prob`.
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:2041: The name tf.nn.fused_batch_norm is deprecated.
Please use tf.compat.v1.nn.fused_batch_norm instead.

Train on 60000 samples, validate on 10000 samples
Epoch 1/25
60000/60000 [==============================] - 487s 8ms/step - loss: 1.1831 - acc: 0.6075 - val_lo
ss: 0.1264 - val_acc: 0.9689
Epoch 2/25
60000/60000 [==============================] - 483s 8ms/step - loss: 0.4453 - acc: 0.8610 - val_lo
ss: 0.0527 - val_acc: 0.9854
Epoch 3/25
60000/60000 [==============================] - 482s 8ms/step - loss: 0.3133 - acc: 0.8920 - val_lo
ss: 0.0580 - val_acc: 0.9829
Epoch 4/25
60000/60000 [==============================] - 483s 8ms/step - loss: 0.2688 - acc: 0.9041 - val_lo
ss: 0.0520 - val_acc: 0.9879
Epoch 5/25
60000/60000 [==============================] - 483s 8ms/step - loss: 0.2424 - acc: 0.9110 - val_lo
ss: 0.0304 - val_acc: 0.9918
Epoch 6/25
60000/60000 [==============================] - 484s 8ms/step - loss: 0.2212 - acc: 0.9167 - val_lo
ss: 0.0366 - val_acc: 0.9905
Epoch 7/25
60000/60000 [==============================] - 483s 8ms/step - loss: 0.2111 - acc: 0.9218 - val_lo
ss: 0.0364 - val_acc: 0.9919
Epoch 8/25
60000/60000 [==============================] - 483s 8ms/step - loss: 0.1993 - acc: 0.9257 - val_lo
ss: 0.0423 - val_acc: 0.9903
Epoch 9/25
60000/60000 [==============================] - 483s 8ms/step - loss: 0.1976 - acc: 0.9259 - val_lo
ss: 0.0370 - val_acc: 0.9913
Epoch 10/25
60000/60000 [==============================] - 483s 8ms/step - loss: 0.1909 - acc: 0.9294 - val_lo
ss: 0.0331 - val_acc: 0.9914
Epoch 11/25
60000/60000 [==============================] - 483s 8ms/step - loss: 0.1820 - acc: 0.9319 - val_lo
ss: 0.0344 - val_acc: 0.9919
Epoch 12/25
60000/60000 [==============================] - 483s 8ms/step - loss: 0.1795 - acc: 0.9343 - val_lo
ss: 0.0319 - val_acc: 0.9925
Epoch 13/25
60000/60000 [==============================] - 483s 8ms/step - loss: 0.1801 - acc: 0.9340 - val_lo
ss: 0.0318 - val_acc: 0.9928
Epoch 14/25
```

```
60000/60000 [==============================] - 483s 8ms/step - loss: 0.1703 - acc: 0.9376 - val_lo
ss: 0.0276 - val_acc: 0.9938
Epoch 15/25
60000/60000 [==============================] - 483s 8ms/step - loss: 0.1724 - acc: 0.9365 - val_lo
ss: 0.0338 - val_acc: 0.9932
Epoch 16/25
60000/60000 [==============================] - 483s 8ms/step - loss: 0.1681 - acc: 0.9396 - val_lo
ss: 0.0320 - val_acc: 0.9933
Epoch 17/25
60000/60000 [==============================] - 484s 8ms/step - loss: 0.1650 - acc: 0.9398 - val_lo
ss: 0.0333 - val_acc: 0.9924
Epoch 18/25
60000/60000 [==============================] - 484s 8ms/step - loss: 0.1593 - acc: 0.9412 - val_lo
ss: 0.0354 - val_acc: 0.9940
Epoch 19/25
60000/60000 [==============================] - 483s 8ms/step - loss: 0.1542 - acc: 0.9436 - val_lo
ss: 0.0289 - val_acc: 0.9937
Epoch 20/25
60000/60000 [==============================] - 482s 8ms/step - loss: 0.1547 - acc: 0.9442 - val_lo
ss: 0.0363 - val_acc: 0.9934
Epoch 21/25
60000/60000 [==============================] - 484s 8ms/step - loss: 0.1529 - acc: 0.9443 - val_lo
ss: 0.0281 - val_acc: 0.9937
Epoch 22/25
60000/60000 [==============================] - 484s 8ms/step - loss: 0.1508 - acc: 0.9448 - val_lo
ss: 0.0310 - val_acc: 0.9947
Epoch 23/25
60000/60000 [==============================] - 485s 8ms/step - loss: 0.1476 - acc: 0.9457 - val_lo
ss: 0.0346 - val_acc: 0.9933
Epoch 24/25
60000/60000 [==============================] - 485s 8ms/step - loss: 0.1472 - acc: 0.9473 - val_lo
ss: 0.0308 - val_acc: 0.9939
Epoch 25/25
60000/60000 [==============================] - 484s 8ms/step - loss: 0.1448 - acc: 0.9460 - val_lo
ss: 0.0446 - val_acc: 0.9927
Test Score:  0.044630775574515794
Test Accuracy:  0.9927
```



In [0]:

3.1.2 Without Batch Normalisation and Dropouts

In [0]:

```
def build_model_BN_3(input_shape, classes):
  model = Sequential()

  model = Sequential()

  model.add(Convolution2D(100, (2, 2), activation='relu', kernel_initializer='he_normal', padding='
same', input_shape=input_shape))

  model.add(Convolution2D(80, (2, 2), activation='relu', kernel_initializer='he_normal', padding='s
ame'))
  model.add(Convolution2D(80, (2, 2), activation='relu', kernel_initializer='he_normal', padding='s
ame'))
```

```
  model.add(MaxPooling2D(pool_size=(3, 3)))

  model.add(Convolution2D(60, (2, 2), activation='relu', kernel_initializer='he_normal', padding='same'))
  model.add(Convolution2D(60, (2, 2), activation='relu', kernel_initializer='he_normal', padding='same'))
  model.add(MaxPooling2D(pool_size=(3, 3)))

  model.add(Convolution2D(40, (2, 2), activation='relu', kernel_initializer='he_normal', padding='same'))
  model.add(Convolution2D(40, (2, 2), activation='relu', kernel_initializer='he_normal', padding='same'))
  model.add(MaxPooling2D(pool_size=(3, 3)))

  model.add(Flatten())
  model.add(Dense(300, activation='relu', kernel_initializer='he_normal'))

  model.add(Dense(classes))
  model.add(Dense(classes,activation="softmax"))

  return model
```

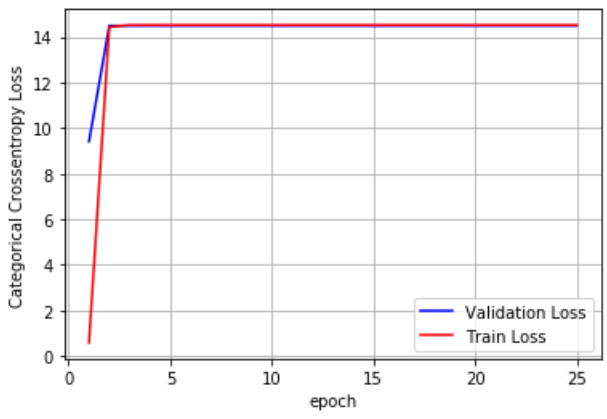
In [0]:

```
def run_model_BN_3():
  batch_size = 128
  epochs = 25

  model = build_model_BN_3(input_shape, num_classes)
  model.compile(loss=keras.losses.categorical_crossentropy,
              optimizer=keras.optimizers.Adadelta(),
              metrics=['accuracy'])

  history = model.fit(x_train, y_train,
            batch_size=batch_size,
            epochs=epochs,
            verbose=1,

            validation_data=(x_test, y_test))
  score = model.evaluate(x_test, y_test, verbose=0)
  print('Test Score: ', score[0])
  print('Test Accuracy: ', score[1])

  fig,ax = plt.subplots(1,1)
  ax.set_xlabel('epoch') ; ax.set_ylabel('Categorical Crossentropy Loss')

  # list of epoch numbers
  x = list(range(1,epochs+1))

  vy = history.history['val_loss']
  ty = history.history['loss']
  plt_dynamic(x, vy, ty, ax, fig)

run_model_BN_3()
```

```
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/backend/tensorflow_backend.py:66: The name tf.get_default_graph is deprecated. Please use tf.compat.v1.get_default_graph instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/backend/tensorflow_backend.py:541: The name tf.placeholder is deprecated. Please use tf.compat.v1.placeholder instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/backend/tensorflow_backend.py:4479: The name tf.truncated_normal is deprecated. Please use tf.random.truncated_normal instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/backend/tensorflow_backend.py:4267: The name tf.nn.max_pool is deprecated. Please use tf.nn.max_pool2d instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/backend/tensorflow_backend.py:4432: The name tf.random_uniform is deprecated. Please use tf.random.uniform instead.
```

```
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/optimizers.py:793: The name t
f.train.Optimizer is deprecated. Please use tf.compat.v1.train.Optimizer instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:3576: The name tf.log is deprecated. Please use tf.ma
th.log instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/tensorflow_core/python/ops/math_grad.py:1424: where (from
tensorflow.python.ops.array_ops) is deprecated and will be removed in a future version.
Instructions for updating:
Use tf.where in 2.0, which has the same broadcast rule as np.where
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:1033: The name tf.assign_add is deprecated. Please us
e tf.compat.v1.assign_add instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:1020: The name tf.assign is deprecated. Please use tf
.compat.v1.assign instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:3005: The name tf.Session is deprecated. Please use t
f.compat.v1.Session instead.

Train on 60000 samples, validate on 10000 samples
Epoch 1/25
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:190: The name tf.get_default_session is deprecated. P
lease use tf.compat.v1.get_default_session instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:197: The name tf.ConfigProto is deprecated. Please us
e tf.compat.v1.ConfigProto instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:207: The name tf.global_variables is deprecated. Plea
se use tf.compat.v1.global_variables instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:216: The name tf.is_variable_initialized is
deprecated. Please use tf.compat.v1.is_variable_initialized instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:223: The name tf.variables_initializer is deprecated.
Please use tf.compat.v1.variables_initializer instead.

60000/60000 [==============================] - 472s 8ms/step - loss: 0.5784 - acc: 0.8449 - val_lo
ss: 9.4123 - val_acc: 0.3832
Epoch 2/25
60000/60000 [==============================] - 469s 8ms/step - loss: 14.4398 - acc: 0.1036 - val_l
oss: 14.4918 - val_acc: 0.1009
Epoch 3/25
60000/60000 [==============================] - 468s 8ms/step - loss: 14.5200 - acc: 0.0992 - val_l
oss: 14.4918 - val_acc: 0.1009
Epoch 4/25
60000/60000 [==============================] - 471s 8ms/step - loss: 14.5200 - acc: 0.0992 - val_l
oss: 14.4918 - val_acc: 0.1009
Epoch 5/25
60000/60000 [==============================] - 473s 8ms/step - loss: 14.5200 - acc: 0.0992 - val_l
oss: 14.4918 - val_acc: 0.1009
Epoch 6/25
60000/60000 [==============================] - 474s 8ms/step - loss: 14.5200 - acc: 0.0992 - val_l
oss: 14.4918 - val_acc: 0.1009
Epoch 7/25
60000/60000 [==============================] - 474s 8ms/step - loss: 14.5200 - acc: 0.0992 - val_l
oss: 14.4918 - val_acc: 0.1009
Epoch 8/25
60000/60000 [==============================] - 473s 8ms/step - loss: 14.5200 - acc: 0.0992 - val_l
oss: 14.4918 - val_acc: 0.1009
Epoch 9/25
60000/60000 [==============================] - 473s 8ms/step - loss: 14.5200 - acc: 0.0992 - val_l
oss: 14.4918 - val_acc: 0.1009
Epoch 10/25
60000/60000 [==============================] - 472s 8ms/step - loss: 14.5200 - acc: 0.0992 - val_l
oss: 14.4918 - val_acc: 0.1009
Epoch 11/25
60000/60000 [==============================] - 472s 8ms/step - loss: 14.5200 - acc: 0.0992 - val_l
```

```
oss: 14.4918 - val_acc: 0.1009
Epoch 12/25
60000/60000 [==============================] - 473s 8ms/step - loss: 14.5200 - acc: 0.0992 - val_l
oss: 14.4918 - val_acc: 0.1009
Epoch 13/25
60000/60000 [==============================] - 477s 8ms/step - loss: 14.5200 - acc: 0.0992 - val_l
oss: 14.4918 - val_acc: 0.1009
Epoch 14/25
60000/60000 [==============================] - 473s 8ms/step - loss: 14.5200 - acc: 0.0991 - val_l
oss: 14.4918 - val_acc: 0.1009
Epoch 15/25
60000/60000 [==============================] - 470s 8ms/step - loss: 14.5200 - acc: 0.0992 - val_l
oss: 14.4918 - val_acc: 0.1009
Epoch 16/25
60000/60000 [==============================] - 468s 8ms/step - loss: 14.5200 - acc: 0.0992 - val_l
oss: 14.4918 - val_acc: 0.1009
Epoch 17/25
60000/60000 [==============================] - 469s 8ms/step - loss: 14.5200 - acc: 0.0992 - val_l
oss: 14.4918 - val_acc: 0.1009
Epoch 18/25
60000/60000 [==============================] - 470s 8ms/step - loss: 14.5200 - acc: 0.0991 - val_l
oss: 14.4918 - val_acc: 0.1009
Epoch 19/25
60000/60000 [==============================] - 472s 8ms/step - loss: 14.5200 - acc: 0.0992 - val_l
oss: 14.4918 - val_acc: 0.1009
Epoch 20/25
60000/60000 [==============================] - 472s 8ms/step - loss: 14.5200 - acc: 0.0992 - val_l
oss: 14.4918 - val_acc: 0.1009
Epoch 21/25
60000/60000 [==============================] - 473s 8ms/step - loss: 14.5200 - acc: 0.0991 - val_l
oss: 14.4918 - val_acc: 0.1009
Epoch 22/25
60000/60000 [==============================] - 473s 8ms/step - loss: 14.5200 - acc: 0.0992 - val_l
oss: 14.4918 - val_acc: 0.1009
Epoch 23/25
60000/60000 [==============================] - 471s 8ms/step - loss: 14.5200 - acc: 0.0991 - val_l
oss: 14.4918 - val_acc: 0.1009
Epoch 24/25
60000/60000 [==============================] - 470s 8ms/step - loss: 14.5200 - acc: 0.0992 - val_l
oss: 14.4918 - val_acc: 0.1009
Epoch 25/25
60000/60000 [==============================] - 470s 8ms/step - loss: 14.5200 - acc: 0.0991 - val_l
oss: 14.4918 - val_acc: 0.1009
Test Score:  14.491779391479492
Test Accuracy:  0.1009
```



In [0]:

3.2 Activation: Sigmoid

3.2.1 With Batch Normalisation and Dropouts

In [0]:

```
def build_model_BN_3(input_shape, classes):
  model = Sequential()

  model = Sequential()

  model.add(Convolution2D(100, (2, 2), activation='sigmoid', kernel_initializer='glorot_normal', pa
dding='same', input_shape=input_shape))
  model.add(Dropout(0.25))

  model.add(Convolution2D(80, (2, 2), activation='sigmoid', kernel_initializer='glorot_normal', pad
ding='same'))
  model.add(Convolution2D(80, (2, 2), activation='sigmoid', kernel_initializer='glorot_normal', pad
ding='same'))
  model.add(MaxPooling2D(pool_size=(3, 3)))
  model.add(BatchNormalization())
  model.add(Dropout(0.25))

  model.add(Convolution2D(60, (2, 2), activation='sigmoid', kernel_initializer='glorot_normal', pad
ding='same'))
  model.add(Convolution2D(60, (2, 2), activation='sigmoid', kernel_initializer='glorot_normal', pad
ding='same'))
  model.add(MaxPooling2D(pool_size=(3, 3)))
  model.add(BatchNormalization())
  model.add(Dropout(0.25))

  model.add(Convolution2D(40, (2, 2), activation='sigmoid', kernel_initializer='glorot_normal', pad
ding='same'))
  model.add(Convolution2D(40, (2, 2), activation='sigmoid', kernel_initializer='glorot_normal', pad
ding='same'))
  model.add(MaxPooling2D(pool_size=(3, 3)))
  model.add(BatchNormalization())
  model.add(Dropout(0.25))

  model.add(Flatten())
  model.add(Dense(300, activation='sigmoid', kernel_initializer='glorot_normal'))
  model.add(BatchNormalization())
  model.add(Dropout(0.5))

  model.add(Dense(classes))
  model.add(BatchNormalization())
  model.add(Dropout(0.5))
  model.add(Dense(classes,activation="softmax"))

  return model
```

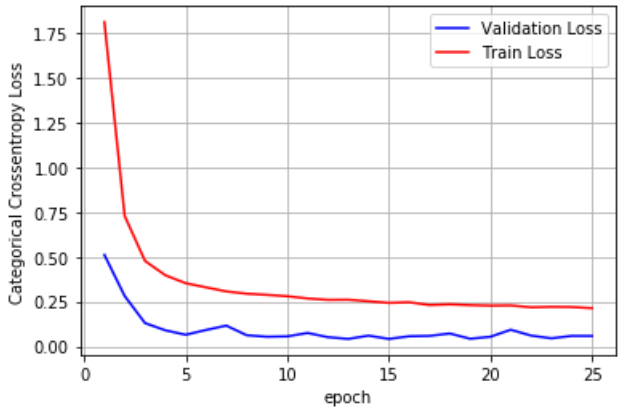
In [8]:

```
def run_model_BN_3():
  batch_size = 128
  epochs = 25

  model = build_model_BN_3(input_shape, num_classes)
  model.compile(loss=keras.losses.categorical_crossentropy,
              optimizer=keras.optimizers.Adadelta(),
              metrics=['accuracy'])

  history = model.fit(x_train, y_train,
            batch_size=batch_size,
            epochs=epochs,
            verbose=1,

            validation_data=(x_test, y_test))
  score = model.evaluate(x_test, y_test, verbose=0)
  print('Test Score: ', score[0])
  print('Test Accuracy: ', score[1])

  fig,ax = plt.subplots(1,1)
  ax.set_xlabel('epoch') ; ax.set_ylabel('Categorical Crossentropy Loss')

  # list of epoch numbers
  x = list(range(1,epochs+1))

  vy = history.history['val_loss']
  ty = history.history['loss']
  plt_dynamic(x, vy, ty, ax, fig)
```

```
run_model_BN_3()
```

```
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:148: The name tf.placeholder_with_default is
deprecated. Please use tf.compat.v1.placeholder_with_default instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:3733: calling dropout (from
tensorflow.python.ops.nn_ops) with keep_prob is deprecated and will be removed in a future
version.
Instructions for updating:
Please use `rate` instead of `keep_prob`. Rate should be set to `rate = 1 - keep_prob`.
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:2041: The name tf.nn.fused_batch_norm is deprecated.
Please use tf.compat.v1.nn.fused_batch_norm instead.

Train on 60000 samples, validate on 10000 samples
Epoch 1/25
60000/60000 [==============================] - 547s 9ms/step - loss: 1.8123 - acc: 0.3881 - val_lo
ss: 0.5113 - val_acc: 0.8680
Epoch 2/25
60000/60000 [==============================] - 544s 9ms/step - loss: 0.7282 - acc: 0.7646 - val_lo
ss: 0.2810 - val_acc: 0.9193
Epoch 3/25
60000/60000 [==============================] - 543s 9ms/step - loss: 0.4774 - acc: 0.8385 - val_lo
ss: 0.1299 - val_acc: 0.9616
Epoch 4/25
60000/60000 [==============================] - 546s 9ms/step - loss: 0.3973 - acc: 0.8568 - val_lo
ss: 0.0896 - val_acc: 0.9739
Epoch 5/25
60000/60000 [==============================] - 546s 9ms/step - loss: 0.3529 - acc: 0.8682 - val_lo
ss: 0.0648 - val_acc: 0.9810
Epoch 6/25
60000/60000 [==============================] - 544s 9ms/step - loss: 0.3297 - acc: 0.8771 - val_lo
ss: 0.0914 - val_acc: 0.9768
Epoch 7/25
60000/60000 [==============================] - 543s 9ms/step - loss: 0.3069 - acc: 0.8831 - val_lo
ss: 0.1158 - val_acc: 0.9675
Epoch 8/25
60000/60000 [==============================] - 539s 9ms/step - loss: 0.2943 - acc: 0.8884 - val_lo
ss: 0.0622 - val_acc: 0.9829
Epoch 9/25
60000/60000 [==============================] - 540s 9ms/step - loss: 0.2877 - acc: 0.8915 - val_lo
ss: 0.0537 - val_acc: 0.9873
Epoch 10/25
60000/60000 [==============================] - 540s 9ms/step - loss: 0.2802 - acc: 0.8952 - val_lo
ss: 0.0557 - val_acc: 0.9845
Epoch 11/25
60000/60000 [==============================] - 539s 9ms/step - loss: 0.2676 - acc: 0.8980 - val_lo
ss: 0.0748 - val_acc: 0.9833
Epoch 12/25
60000/60000 [==============================] - 544s 9ms/step - loss: 0.2598 - acc: 0.9007 - val_lo
ss: 0.0514 - val_acc: 0.9861
Epoch 13/25
60000/60000 [==============================] - 549s 9ms/step - loss: 0.2605 - acc: 0.9006 - val_lo
ss: 0.0416 - val_acc: 0.9901
Epoch 14/25
60000/60000 [==============================] - 546s 9ms/step - loss: 0.2519 - acc: 0.9039 - val_lo
ss: 0.0600 - val_acc: 0.9869
Epoch 15/25
60000/60000 [==============================] - 546s 9ms/step - loss: 0.2429 - acc: 0.9085 - val_lo
ss: 0.0415 - val_acc: 0.9898
Epoch 16/25
60000/60000 [==============================] - 547s 9ms/step - loss: 0.2463 - acc: 0.9059 - val_lo
ss: 0.0563 - val_acc: 0.9873
Epoch 17/25
60000/60000 [==============================] - 548s 9ms/step - loss: 0.2310 - acc: 0.9116 - val_lo
ss: 0.0585 - val_acc: 0.9861
Epoch 18/25
60000/60000 [==============================] - 549s 9ms/step - loss: 0.2347 - acc: 0.9104 - val_lo
ss: 0.0718 - val_acc: 0.9834
Epoch 19/25
60000/60000 [==============================] - 546s 9ms/step - loss: 0.2303 - acc: 0.9118 - val_lo
ss: 0.0425 - val_acc: 0.9901
Epoch 20/25
60000/60000 [==============================] - 545s 9ms/step - loss: 0.2276 - acc: 0.9135 - val lo
```

```
ss: 0.0537 - val_acc: 0.9877
Epoch 21/25
60000/60000 [==============================] - 548s 9ms/step - loss: 0.2287 - acc: 0.9140 - val_lo
ss: 0.0928 - val_acc: 0.9820
Epoch 22/25
60000/60000 [==============================] - 549s 9ms/step - loss: 0.2182 - acc: 0.9170 - val_lo
ss: 0.0601 - val_acc: 0.9888
Epoch 23/25
60000/60000 [==============================] - 552s 9ms/step - loss: 0.2209 - acc: 0.9166 - val_lo
ss: 0.0449 - val_acc: 0.9891
Epoch 24/25
60000/60000 [==============================] - 547s 9ms/step - loss: 0.2198 - acc: 0.9156 - val_lo
ss: 0.0584 - val_acc: 0.9866
Epoch 25/25
60000/60000 [==============================] - 547s 9ms/step - loss: 0.2134 - acc: 0.9190 - val_lo
ss: 0.0580 - val_acc: 0.9887
Test Score:  0.05804685096810426
Test Accuracy:  0.9887
```



In [0]:

```
```

3.2.2 Without Batch Normalisation and Dropouts

In [0]:

```
def build_model_BN_3(input_shape, classes):
  model = Sequential()

  model = Sequential()

  model.add(Convolution2D(100, (2, 2), activation='sigmoid', kernel_initializer='glorot_normal', pa
dding='same', input_shape=input_shape))

  model.add(Convolution2D(80, (2, 2), activation='sigmoid', kernel_initializer='glorot_normal', pad
ding='same'))
  model.add(Convolution2D(80, (2, 2), activation='sigmoid', kernel_initializer='glorot_normal', pad
ding='same'))
  model.add(MaxPooling2D(pool_size=(3, 3)))

  model.add(Convolution2D(60, (2, 2), activation='sigmoid', kernel_initializer='glorot_normal', pad
ding='same'))
  model.add(Convolution2D(60, (2, 2), activation='sigmoid', kernel_initializer='glorot_normal', pad
ding='same'))
  model.add(MaxPooling2D(pool_size=(3, 3)))

  model.add(Convolution2D(40, (2, 2), activation='sigmoid', kernel_initializer='glorot_normal', pad
ding='same'))
  model.add(Convolution2D(40, (2, 2), activation='sigmoid', kernel_initializer='glorot_normal', pad
ding='same'))
  model.add(MaxPooling2D(pool_size=(3, 3)))

  model.add(Flatten())
  model.add(Dense(300, activation='sigmoid', kernel_initializer='glorot_normal'))

  model.add(Dense(classes))
```

```
  model.add(Dense(classes,activation="softmax"))

  return model
```

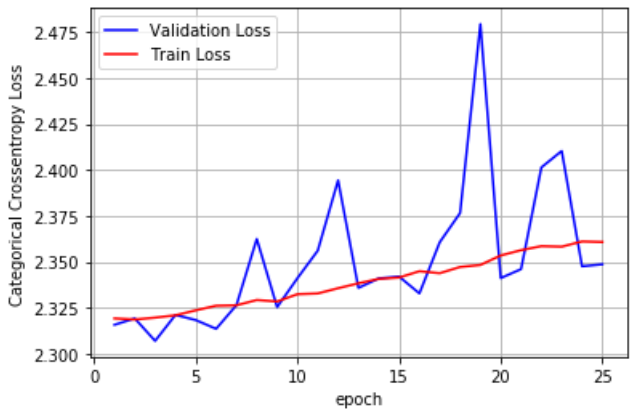
In [7]:

```
def run_model_BN_3():
  batch_size = 128
  epochs = 25

  model = build_model_BN_3(input_shape, num_classes)
  model.compile(loss=keras.losses.categorical_crossentropy,
              optimizer=keras.optimizers.Adadelta(),
              metrics=['accuracy'])

  history = model.fit(x_train, y_train,
            batch_size=batch_size,
            epochs=epochs,
            verbose=1,

            validation_data=(x_test, y_test))
  score = model.evaluate(x_test, y_test, verbose=0)
  print('Test Score: ', score[0])
  print('Test Accuracy: ', score[1])

  fig,ax = plt.subplots(1,1)
  ax.set_xlabel('epoch') ; ax.set_ylabel('Categorical Crossentropy Loss')

  # list of epoch numbers
  x = list(range(1,epochs+1))

  vy = history.history['val_loss']
  ty = history.history['loss']
  plt_dynamic(x, vy, ty, ax, fig)

run_model_BN_3()
```

```
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:66: The name tf.get_default_graph is deprecated. Plea
se use tf.compat.v1.get_default_graph instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:541: The name tf.placeholder is deprecated. Please us
e tf.compat.v1.placeholder instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:4479: The name tf.truncated_normal is deprecated. Ple
ase use tf.random.truncated_normal instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:4267: The name tf.nn.max_pool is deprecated. Please u
se tf.nn.max_pool2d instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:4432: The name tf.random_uniform is deprecated. Pleas
e use tf.random.uniform instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/optimizers.py:793: The name t
f.train.Optimizer is deprecated. Please use tf.compat.v1.train.Optimizer instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:3576: The name tf.log is deprecated. Please use tf.ma
th.log instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/tensorflow_core/python/ops/math_grad.py:1424: where (from
tensorflow.python.ops.array_ops) is deprecated and will be removed in a future version.
Instructions for updating:
Use tf.where in 2.0, which has the same broadcast rule as np.where
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:1033: The name tf.assign_add is deprecated. Please us
e tf.compat.v1.assign_add instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:1020: The name tf.assign is deprecated. Please use tf
```

```
.compat.v1.assign instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:3005: The name tf.Session is deprecated. Please use t
f.compat.v1.Session instead.

Train on 60000 samples, validate on 10000 samples
Epoch 1/25
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:190: The name tf.get_default_session is deprecated. P
lease use tf.compat.v1.get_default_session instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:197: The name tf.ConfigProto is deprecated. Please us
e tf.compat.v1.ConfigProto instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:207: The name tf.global_variables is deprecated. Plea
se use tf.compat.v1.global_variables instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:216: The name tf.is_variable_initialized is
deprecated. Please use tf.compat.v1.is_variable_initialized instead.

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-
packages/keras/backend/tensorflow_backend.py:223: The name tf.variables_initializer is deprecated.
Please use tf.compat.v1.variables_initializer instead.

60000/60000 [==============================] - 513s 9ms/step - loss: 2.3191 - acc: 0.1032 - val_lo
ss: 2.3156 - val_acc: 0.1032
Epoch 2/25
60000/60000 [==============================] - 510s 8ms/step - loss: 2.3185 - acc: 0.1004 - val_lo
ss: 2.3191 - val_acc: 0.1135
Epoch 3/25
60000/60000 [==============================] - 509s 8ms/step - loss: 2.3195 - acc: 0.1023 - val_lo
ss: 2.3069 - val_acc: 0.1032
Epoch 4/25
60000/60000 [==============================] - 508s 8ms/step - loss: 2.3208 - acc: 0.1042 - val_lo
ss: 2.3210 - val_acc: 0.1032
Epoch 5/25
60000/60000 [==============================] - 512s 9ms/step - loss: 2.3235 - acc: 0.1030 - val_lo
ss: 2.3182 - val_acc: 0.1135
Epoch 6/25
60000/60000 [==============================] - 518s 9ms/step - loss: 2.3260 - acc: 0.1034 - val_lo
ss: 2.3134 - val_acc: 0.1135
Epoch 7/25
60000/60000 [==============================] - 514s 9ms/step - loss: 2.3263 - acc: 0.1050 - val_lo
ss: 2.3263 - val_acc: 0.1028
Epoch 8/25
60000/60000 [==============================] - 507s 8ms/step - loss: 2.3291 - acc: 0.1030 - val_lo
ss: 2.3624 - val_acc: 0.1009
Epoch 9/25
60000/60000 [==============================] - 512s 9ms/step - loss: 2.3283 - acc: 0.1022 - val_lo
ss: 2.3253 - val_acc: 0.1135
Epoch 10/25
60000/60000 [==============================] - 524s 9ms/step - loss: 2.3323 - acc: 0.1024 - val_lo
ss: 2.3410 - val_acc: 0.1010
Epoch 11/25
60000/60000 [==============================] - 518s 9ms/step - loss: 2.3327 - acc: 0.1008 - val_lo
ss: 2.3561 - val_acc: 0.0958
Epoch 12/25
60000/60000 [==============================] - 517s 9ms/step - loss: 2.3356 - acc: 0.1009 - val_lo
ss: 2.3944 - val_acc: 0.1010
Epoch 13/25
60000/60000 [==============================] - 516s 9ms/step - loss: 2.3382 - acc: 0.0998 - val_lo
ss: 2.3357 - val_acc: 0.0974
Epoch 14/25
60000/60000 [==============================] - 519s 9ms/step - loss: 2.3407 - acc: 0.1010 - val_lo
ss: 2.3409 - val_acc: 0.0958
Epoch 15/25
60000/60000 [==============================] - 517s 9ms/step - loss: 2.3414 - acc: 0.1017 - val_lo
ss: 2.3419 - val_acc: 0.1135
Epoch 16/25
60000/60000 [==============================] - 514s 9ms/step - loss: 2.3448 - acc: 0.1024 - val_lo
ss: 2.3327 - val_acc: 0.1009
Epoch 17/25
60000/60000 [==============================] - 514s 9ms/step - loss: 2.3437 - acc: 0.1022 - val_lo
```

```
ss: 2.3606 - val_acc: 0.0982
Epoch 18/25
60000/60000 [==============================] - 515s 9ms/step - loss: 2.3471 - acc: 0.1031 - val_lo
ss: 2.3765 - val_acc: 0.1028
Epoch 19/25
60000/60000 [==============================] - 514s 9ms/step - loss: 2.3482 - acc: 0.1039 - val_lo
ss: 2.4795 - val_acc: 0.1010
Epoch 20/25
60000/60000 [==============================] - 514s 9ms/step - loss: 2.3534 - acc: 0.1029 - val_lo
ss: 2.3411 - val_acc: 0.0958
Epoch 21/25
60000/60000 [==============================] - 515s 9ms/step - loss: 2.3563 - acc: 0.1013 - val_lo
ss: 2.3460 - val_acc: 0.1010
Epoch 22/25
60000/60000 [==============================] - 518s 9ms/step - loss: 2.3585 - acc: 0.1007 - val_lo
ss: 2.4014 - val_acc: 0.0958
Epoch 23/25
60000/60000 [==============================] - 517s 9ms/step - loss: 2.3582 - acc: 0.1011 - val_lo
ss: 2.4103 - val_acc: 0.0982
Epoch 24/25
60000/60000 [==============================] - 513s 9ms/step - loss: 2.3610 - acc: 0.1020 - val_lo
ss: 2.3475 - val_acc: 0.1009
Epoch 25/25
60000/60000 [==============================] - 513s 9ms/step - loss: 2.3608 - acc: 0.1009 - val_lo
ss: 2.3486 - val_acc: 0.0958
Test Score:  2.3485770217895507
Test Accuracy:  0.0958
```



Results:

In [11]:

```
from prettytable import PrettyTable

table = PrettyTable()

table.field_names = ['CNN Architecture No.', 'Activation', 'Batch Normalisation and Dropouts',
'Test Accuracy']

table.add_row(['1','Relu', 'Yes','99.08'])
table.add_row(['1','Relu', 'No','99.13'])
table.add_row(['1','Sigmoid', 'Yes','99.08'])
table.add_row(['1','Sigmoid', 'No','09.58'])

table.add_row(['2','Relu', 'Yes','99.58'])
table.add_row(['2','Relu', 'No','11.35'])
table.add_row(['2','Sigmoid', 'Yes','99.20'])
table.add_row(['2','Sigmoid', 'No','10.10'])

table.add_row(['3','Relu', 'Yes','99.27'])
table.add_row(['3','Relu', 'No','10.09'])
table.add_row(['3','Sigmoid', 'Yes','98.87'])
table.add_row(['3','Sigmoid', 'No','09.58'])

print(table)
```

```
+---------------------+------------+---------------------------------+---------------+
```

CNN Architecture No.	Activation	Batch Normalisation and Dropouts	Test Accuracy
1	Relu	Yes	99.08
1	Relu	No	99.13
1	Sigmoid	Yes	99.08
1	Sigmoid	No	09.58
2	Relu	Yes	99.58
2	Relu	No	11.35
2	Sigmoid	Yes	99.20
2	Sigmoid	No	10.10
3	Relu	Yes	99.27
3	Relu	No	10.09
3	Sigmoid	Yes	98.87
3	Sigmoid	No	09.58

Conclusion:

As we construct deeper CNN's, we need to add Batch Normalisation and Dropouts to maintain a good accuracy score.

In [0]: