```
%matplotlib inline
import matplotlib.pyplot as plt
import numpy as np
import time
# 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, 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()
```

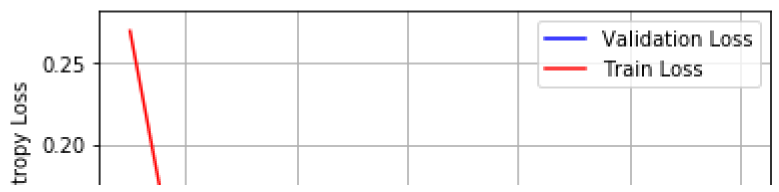
```
# Credits: https://github.com/keras-team/keras/blob/master/examples/mnist_cnn.py


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 Conv2D, MaxPooling2D
from keras import backend as K

batch_size = 128
num_classes = 10
epochs = 12

# 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)

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
```

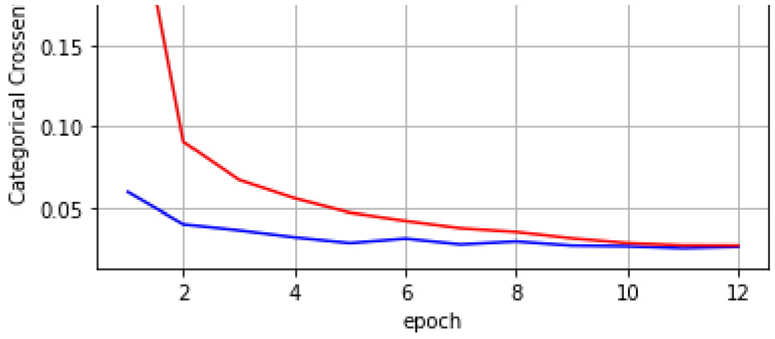
```
y_train = keras.utils.to_categorical(y_train, num_classes)
y_test = keras.utils.to_categorical(y_test, num_classes)

model = Sequential()
model.add(Conv2D(32, kernel_size=(3, 3),
                 activation='relu',
                 input_shape=input_shape))
model.add(Conv2D(64, (3, 3), activation='relu'))
model.add(MaxPooling2D(pool_size=(2, 2)))
model.add(Dropout(0.25))
model.add(Flatten())
model.add(Dense(128, activation='relu'))
model.add(Dropout(0.5))
model.add(Dense(num_classes, activation='softmax'))

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

```
x_train shape: (60000, 28, 28, 1)
60000 train samples
10000 test samples
Train on 60000 samples, validate on 10000 samples
Epoch 1/12
60000/60000 [==============================] - 6s 104us/step - loss: 0.2698 - acc: 0
```

```
60000/60000 [==============================] - 6s 104us/step - loss: 0.2698 - acc: 0.
Epoch 2/12
60000/60000 [==============================] - 4s 65us/step - loss: 0.0904 - acc: 0.9
Epoch 3/12
60000/60000 [==============================] - 4s 66us/step - loss: 0.0670 - acc: 0.9
Epoch 4/12
60000/60000 [==============================] - 4s 66us/step - loss: 0.0557 - acc: 0.9
Epoch 5/12
60000/60000 [==============================] - 4s 66us/step - loss: 0.0468 - acc: 0.9
Epoch 6/12
60000/60000 [==============================] - 4s 65us/step - loss: 0.0418 - acc: 0.9
Epoch 7/12
60000/60000 [==============================] - 4s 65us/step - loss: 0.0373 - acc: 0.9
Epoch 8/12
60000/60000 [==============================] - 4s 65us/step - loss: 0.0350 - acc: 0.9
Epoch 9/12
60000/60000 [==============================] - 4s 65us/step - loss: 0.0311 - acc: 0.9
Epoch 10/12
60000/60000 [==============================] - 4s 65us/step - loss: 0.0281 - acc: 0.9
Epoch 11/12
60000/60000 [==============================] - 4s 65us/step - loss: 0.0267 - acc: 0.9
Epoch 12/12
60000/60000 [==============================] - 4s 65us/step - loss: 0.0266 - acc: 0.9
Test loss: 0.025834757073652508
Test accuracy: 0.9917
```

```
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))

# print(history.history.keys())
# dict_keys(['val_loss', 'val_acc', 'loss', 'acc'])
# history = model_drop.fit(X_train, Y_train, batch_size=batch_size, epochs=nb_epoch, verbo

# we will get val_loss and val_acc only when you pass the paramter validation_data
# val_loss : validation loss
# val_acc : validation accuracy

# loss : training loss
# acc : train accuracy
# for each key in histrory.histrory we will have a list of length equal to number of epoch

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





```
## assignment
```

Assignment

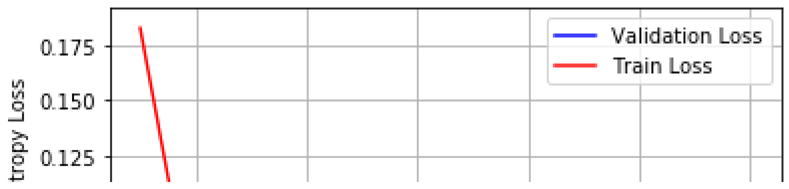
3 LAYER

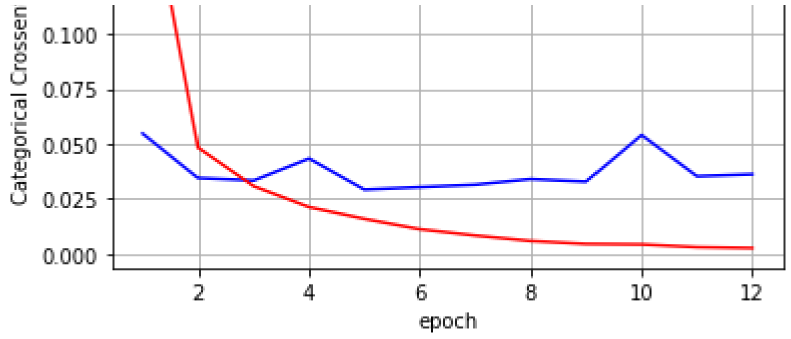
3 LAYER OF CNN WITHOUT POOLING AND DROPOUT and batch nor

```
model = Sequential()
model.add(Conv2D(32, kernel_size=(5, 5),
                 activation='relu',
                 input_shape=input_shape))
model.add(Conv2D(64, (3, 3), activation='relu'))
model.add(Conv2D(64, (2, 2), activation='relu'))
#model.add(MaxPooling2D(pool_size=(2, 2)))
model.add(Dropout(0.25))
model.add(Flatten())
model.add(Dense(128, activation='relu'))
#model.add(Dropout(0.5))

model.add(Dense(num_classes, activation='softmax'))

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

```
Train on 60000 samples, validate on 10000 samples
Epoch 1/12
60000/60000 [==============================] - 8s 132us/step - loss: 0.1827 - acc: 0.
Epoch 2/12
60000/60000 [==============================] - 5s 87us/step - loss: 0.0483 - acc: 0.9
Epoch 3/12
60000/60000 [==============================] - 5s 87us/step - loss: 0.0308 - acc: 0.9
Epoch 4/12
60000/60000 [==============================] - 5s 87us/step - loss: 0.0213 - acc: 0.9
Epoch 5/12
60000/60000 [==============================] - 5s 87us/step - loss: 0.0160 - acc: 0.9
Epoch 6/12
60000/60000 [==============================] - 5s 86us/step - loss: 0.0113 - acc: 0.9
Epoch 7/12
60000/60000 [==============================] - 5s 87us/step - loss: 0.0085 - acc: 0.9
Epoch 8/12
60000/60000 [==============================] - 5s 87us/step - loss: 0.0060 - acc: 0.9
Epoch 9/12
60000/60000 [==============================] - 5s 86us/step - loss: 0.0046 - acc: 0.9
Epoch 10/12
60000/60000 [==============================] - 5s 86us/step - loss: 0.0044 - acc: 0.9
Epoch 11/12
60000/60000 [==============================] - 5s 87us/step - loss: 0.0032 - acc: 0.9
Epoch 12/12
60000/60000 [==============================] - 5s 86us/step - loss: 0.0028 - acc: 0.9
Test loss: 0.036265366634226 69
Test accuracy: 0.9913
```

```
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))

# print(history.history.keys())
# dict_keys(['val_loss', 'val_acc', 'loss', 'acc'])
# history = model_drop.fit(X_train, Y_train, batch_size=batch_size, epochs=nb_epoch, verbo

# we will get val_loss and val_acc only when you pass the paramter validation_data
# val_loss : validation loss
# val_acc : validation accuracy

# loss : training loss
# acc : train accuracy
# for each key in histrory.histrory we will have a list of length equal to number of epoch

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





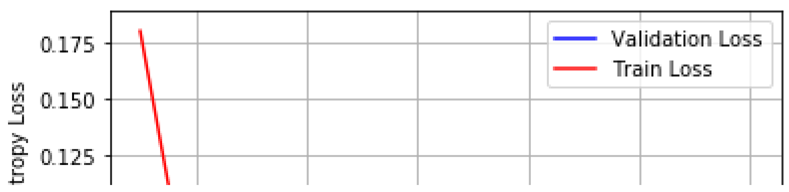
3 LAYER OF CNN WITh POOLING AND without DROPOUT

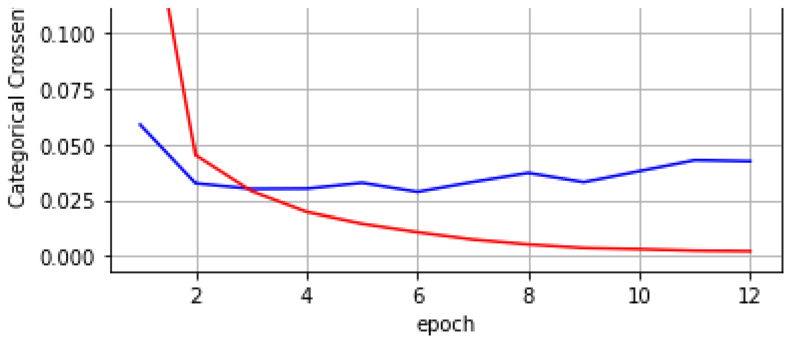
```
model = Sequential()
model.add(Conv2D(32, kernel_size=(5, 5),
                 activation='relu',
                 input_shape=input_shape))
model.add(Conv2D(64, (3, 3), activation='relu'))
model.add(Conv2D(64, (2, 2), activation='relu'))
model.add(MaxPooling2D(pool_size=(2, 2)))
#model.add(Dropout(0.25))
model.add(Flatten())
model.add(Dense(128, activation='relu'))
#model.add(Dropout(0.5))
model.add(Dense(num_classes, activation='softmax'))

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

```
Train on 60000 samples, validate on 10000 samples
Epoch 1/12
60000/60000 [==============================] - 7s 123us/step - loss: 0.1806 - acc: 0.
Epoch 2/12
60000/60000 [==============================] - 4s 72us/step - loss: 0.0451 - acc: 0.9
```

```
Epoch 3/12
60000/60000 [==============================] - 4s 71us/step - loss: 0.0290 - acc: 0.9
Epoch 4/12
60000/60000 [==============================] - 4s 71us/step - loss: 0.0196 - acc: 0.9
Epoch 5/12
60000/60000 [==============================] - 4s 71us/step - loss: 0.0144 - acc: 0.9
Epoch 6/12
60000/60000 [==============================] - 4s 71us/step - loss: 0.0106 - acc: 0.9
Epoch 7/12
60000/60000 [==============================] - 4s 73us/step - loss: 0.0073 - acc: 0.9
Epoch 8/12
60000/60000 [==============================] - 4s 74us/step - loss: 0.0051 - acc: 0.9
Epoch 9/12
60000/60000 [==============================] - 4s 71us/step - loss: 0.0035 - acc: 0.9
Epoch 10/12
60000/60000 [==============================] - 4s 70us/step - loss: 0.0030 - acc: 0.9
Epoch 11/12
60000/60000 [==============================] - 4s 70us/step - loss: 0.0023 - acc: 0.9
Epoch 12/12
60000/60000 [==============================] - 4s 70us/step - loss: 0.0021 - acc: 0.9
Test loss: 0.0424302650914896
Test accuracy: 0.991
```

```
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))

# print(history.history.keys())
# dict_keys(['val_loss', 'val_acc', 'loss', 'acc'])
# history = model_drop.fit(X_train, Y_train, batch_size=batch_size, epochs=nb_epoch, verbo

# we will get val_loss and val_acc only when you pass the paramter validation_data
# val_loss : validation loss
# val_acc : validation accuracy

# loss : training loss
# acc : train accuracy
# for each key in histrory.histrory we will have a list of length equal to number of epoch

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





```
## 3 LAYER OF CNN WITh POOLING AND without DROPOUT
```

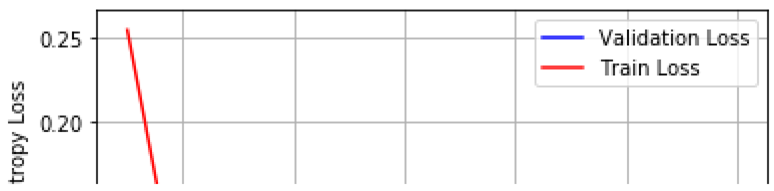
3 LAYER OF CNN WITh POOLING AND with DROPOUT

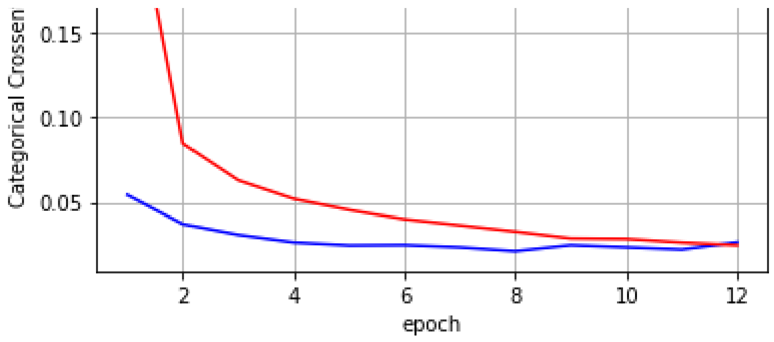
```
model = Sequential()
model.add(Conv2D(32, kernel_size=(5, 5),
                 activation='relu',
                 input_shape=input_shape))
model.add(Conv2D(64, (3, 3), activation='relu'))
model.add(Conv2D(64, (2, 2), activation='relu'))
model.add(MaxPooling2D(pool_size=(2, 2)))
model.add(Dropout(0.25))
model.add(Flatten())
model.add(Dense(128, activation='relu'))
model.add(Dropout(0.5))
model.add(Dense(num_classes, activation='softmax'))

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

```
Train on 60000 samples, validate on 10000 samples
Epoch 1/12
60000/60000 [==============================] - 7s 125us/step - loss: 0.2545 - acc: 0.
Epoch 2/12
60000/60000 [==============================] - 4s 74us/step - loss: 0.0844 - acc: 0.9
```

```
Epoch 3/12
60000/60000 [==============================] - 4s 74us/step - loss: 0.0628 - acc: 0.9
Epoch 4/12
60000/60000 [==============================] - 4s 73us/step - loss: 0.0519 - acc: 0.9
Epoch 5/12
60000/60000 [==============================] - 4s 74us/step - loss: 0.0455 - acc: 0.9
Epoch 6/12
60000/60000 [==============================] - 4s 75us/step - loss: 0.0399 - acc: 0.9
Epoch 7/12
60000/60000 [==============================] - 5s 75us/step - loss: 0.0363 - acc: 0.9
Epoch 8/12
60000/60000 [==============================] - 5s 76us/step - loss: 0.0327 - acc: 0.9
Epoch 9/12
60000/60000 [==============================] - 5s 77us/step - loss: 0.0287 - acc: 0.9
Epoch 10/12
60000/60000 [==============================] - 5s 77us/step - loss: 0.0284 - acc: 0.9
Epoch 11/12
60000/60000 [==============================] - 4s 74us/step - loss: 0.0263 - acc: 0.9
Epoch 12/12
60000/60000 [==============================] - 4s 75us/step - loss: 0.0247 - acc: 0.9
Test loss: 0.026455390622706691
Test accuracy: 0.9919
```

```python
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))

# print(history.history.keys())
# dict_keys(['val_loss', 'val_acc', 'loss', 'acc'])
# history = model_drop.fit(X_train, Y_train, batch_size=batch_size, epochs=nb_epoch, verbo

# we will get val_loss and val_acc only when you pass the paramter validation_data
# val_loss : validation loss
# val_acc : validation accuracy

# loss : training loss
# acc : train accuracy
# for each key in histrory.histrory we will have a list of length equal to number of epoch

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





Double-click (or enter) to edit

5 CNN LAYER

5 LAYER CNN WITHOUT POOL AND DROPOUT

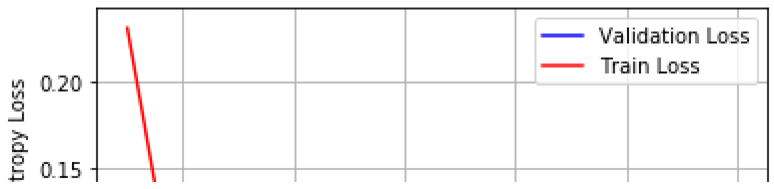
Double-click (or enter) to edit

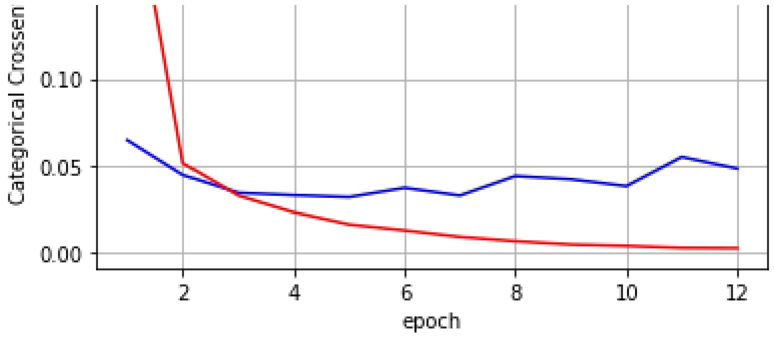
```
model = Sequential()
model.add(Conv2D(64, kernel_size=(5, 5),
                 activation='relu',
                 input_shape=input_shape))
model.add(Conv2D(32, (4, 4), activation='relu'))
model.add(Conv2D(64, (3, 3), activation='relu'))
model.add(Conv2D(64, (2, 2), activation='relu'))
model.add(Conv2D(32, (2, 2), activation='relu'))
#model.add(MaxPooling2D(pool_size=(2, 2)))
#model.add(Dropout(0.25))
model.add(Flatten())
model.add(Dense(128, activation='relu'))
#model.add(Dropout(0.5))
model.add(Dense(num_classes, activation='softmax'))

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

```
Train on 60000 samples, validate on 10000 samples
Epoch 1/12
60000/60000 [==============================] - 9s 146us/step - loss: 0.2313 - acc: 0.
```

```
Epoch 2/12
60000/60000 [==============================] - 5s 91us/step - loss: 0.0513 - acc: 0.9
Epoch 3/12
60000/60000 [==============================] - 5s 91us/step - loss: 0.0326 - acc: 0.9
Epoch 4/12
60000/60000 [==============================] - 5s 91us/step - loss: 0.0230 - acc: 0.9
Epoch 5/12
60000/60000 [==============================] - 5s 91us/step - loss: 0.0160 - acc: 0.9
Epoch 6/12
60000/60000 [==============================] - 5s 91us/step - loss: 0.0126 - acc: 0.9
Epoch 7/12
60000/60000 [==============================] - 5s 90us/step - loss: 0.0089 - acc: 0.9
Epoch 8/12
60000/60000 [==============================] - 5s 92us/step - loss: 0.0064 - acc: 0.9
Epoch 9/12
60000/60000 [==============================] - 6s 93us/step - loss: 0.0045 - acc: 0.9
Epoch 10/12
60000/60000 [==============================] - 6s 93us/step - loss: 0.0037 - acc: 0.9
Epoch 11/12
60000/60000 [==============================] - 5s 90us/step - loss: 0.0026 - acc: 0.9
Epoch 12/12
60000/60000 [==============================] - 5s 91us/step - loss: 0.0024 - acc: 0.9
Test loss: 0.04818914521079446
Test accuracy: 0.9911
```

```
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))

# print(history.history.keys())
# dict_keys(['val_loss', 'val_acc', 'loss', 'acc'])
# history = model_drop.fit(X_train, Y_train, batch_size=batch_size, epochs=nb_epoch, verbo

# we will get val_loss and val_acc only when you pass the paramter validation_data
# val_loss : validation loss
# val_acc : validation accuracy

# loss : training loss
# acc : train accuracy
# for each key in histrory.histrory we will have a list of length equal to number of epoch

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





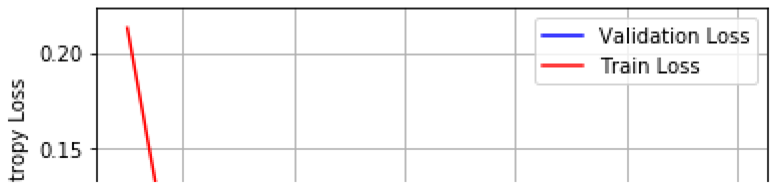
5 LAYER CNN WIT POOL AND WITHOUT DROPOUT

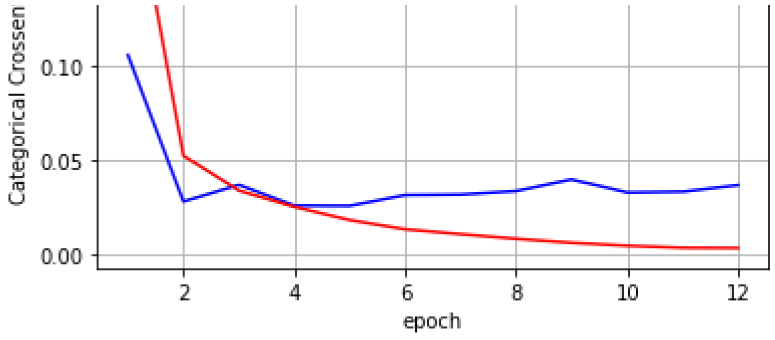
```
model = Sequential()
model.add(Conv2D(64, kernel_size=(5, 5),
                 activation='relu',
                 input_shape=input_shape))
model.add(Conv2D(32, (4, 4), activation='relu'))
model.add(Conv2D(64, (3, 3), activation='relu'))
model.add(Conv2D(64, (2, 2), activation='relu'))
model.add(Conv2D(32, (2, 2), activation='relu'))
model.add(MaxPooling2D(pool_size=(2, 2)))
#model.add(Dropout(0.25))
model.add(Flatten())
model.add(Dense(128, activation='relu'))
#model.add(Dropout(0.5))
model.add(Dense(num_classes, activation='softmax'))

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

```
Train on 60000 samples, validate on 10000 samples
Epoch 1/12
60000/60000 [==============================] - 9s 154us/step - loss: 0.2131 - acc: 0.
Epoch 2/12
60000/60000 [==============================] - 5s 89us/step - loss: 0.0524 - acc: 0.9
```

```
Epoch 3/12
60000/60000 [==============================] - 5s 90us/step - loss: 0.0340 - acc: 0.9
Epoch 4/12
60000/60000 [==============================] - 5s 91us/step - loss: 0.0253 - acc: 0.9
Epoch 5/12
60000/60000 [==============================] - 5s 90us/step - loss: 0.0184 - acc: 0.9
Epoch 6/12
60000/60000 [==============================] - 6s 92us/step - loss: 0.0136 - acc: 0.9
Epoch 7/12
60000/60000 [==============================] - 5s 90us/step - loss: 0.0110 - acc: 0.9
Epoch 8/12
60000/60000 [==============================] - 6s 95us/step - loss: 0.0086 - acc: 0.9
Epoch 9/12
60000/60000 [==============================] - 6s 92us/step - loss: 0.0065 - acc: 0.9
Epoch 10/12
60000/60000 [==============================] - 5s 91us/step - loss: 0.0049 - acc: 0.9
Epoch 11/12
60000/60000 [==============================] - 5s 90us/step - loss: 0.0038 - acc: 0.9
Epoch 12/12
60000/60000 [==============================] - 5s 90us/step - loss: 0.0037 - acc: 0.9
Test loss: 0.036880395430549655
Test accuracy: 0.992
```

```
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))

# print(history.history.keys())
# dict_keys(['val_loss', 'val_acc', 'loss', 'acc'])
# history = model_drop.fit(X_train, Y_train, batch_size=batch_size, epochs=nb_epoch, verbo

# we will get val_loss and val_acc only when you pass the paramter validation_data
# val_loss : validation loss
# val_acc : validation accuracy

# loss : training loss
# acc : train accuracy
# for each key in histrory.histrory we will have a list of length equal to number of epoch

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





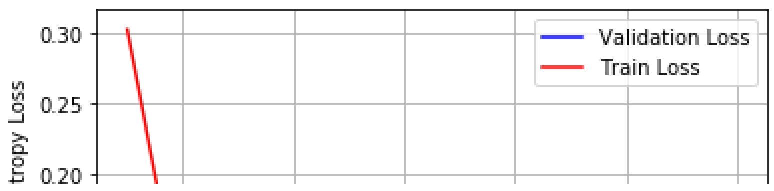
5 LAYER CNN WIT POOL AND WITH DROPOUT

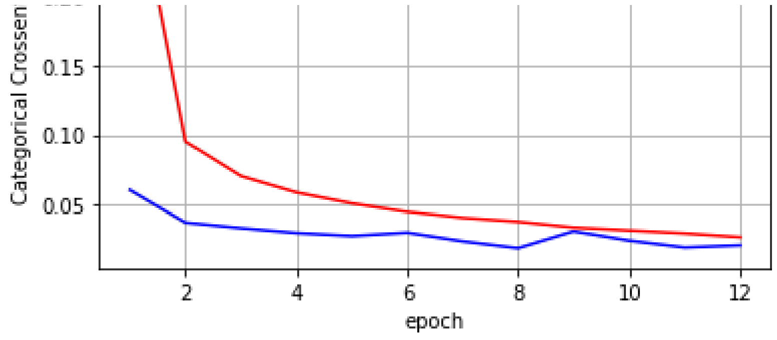
```
model = Sequential()
model.add(Conv2D(64, kernel_size=(5, 5),
                 activation='relu',
                 input_shape=input_shape))
model.add(Conv2D(32, (4, 4), activation='relu'))
model.add(Conv2D(64, (3, 3), activation='relu'))
model.add(Conv2D(64, (2, 2), activation='relu'))
model.add(Conv2D(32, (2, 2), activation='relu'))
model.add(MaxPooling2D(pool_size=(2, 2)))
model.add(Dropout(0.25))
model.add(Flatten())
model.add(Dense(128, activation='relu'))
model.add(Dropout(0.5))
model.add(Dense(num_classes, activation='softmax'))

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

```
Train on 60000 samples, validate on 10000 samples
Epoch 1/12
60000/60000 [==============================] - 9s 153us/step - loss: 0.3028 - acc: 0.
Epoch 2/12
60000/60000 [==============================] - 6s 93us/step - loss: 0.0951 - acc: 0.9
```

```
Epoch 3/12
60000/60000 [==============================] - 6s 93us/step - loss: 0.0705 - acc: 0.9
Epoch 4/12
60000/60000 [==============================] - 6s 92us/step - loss: 0.0589 - acc: 0.9
Epoch 5/12
60000/60000 [==============================] - 6s 93us/step - loss: 0.0511 - acc: 0.9
Epoch 6/12
60000/60000 [==============================] - 6s 94us/step - loss: 0.0450 - acc: 0.9
Epoch 7/12
60000/60000 [==============================] - 6s 92us/step - loss: 0.0406 - acc: 0.9
Epoch 8/12
60000/60000 [==============================] - 6s 93us/step - loss: 0.0379 - acc: 0.9
Epoch 9/12
60000/60000 [==============================] - 6s 92us/step - loss: 0.0338 - acc: 0.9
Epoch 10/12
60000/60000 [==============================] - 6s 93us/step - loss: 0.0317 - acc: 0.9
Epoch 11/12
60000/60000 [==============================] - 6s 93us/step - loss: 0.0296 - acc: 0.9
Epoch 12/12
60000/60000 [==============================] - 6s 92us/step - loss: 0.0269 - acc: 0.9
Test loss: 0.021167633676879945
Test accuracy: 0.9924
```

```python
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))

# print(history.history.keys())
# dict_keys(['val_loss', 'val_acc', 'loss', 'acc'])
# history = model_drop.fit(X_train, Y_train, batch_size=batch_size, epochs=nb_epoch, verbo

# we will get val_loss and val_acc only when you pass the paramter validation_data
# val_loss : validation loss
# val_acc : validation accuracy

# loss : training loss
# acc : train accuracy
# for each key in histrory.histrory we will have a list of length equal to number of epoch

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





7 LAYERS CNN

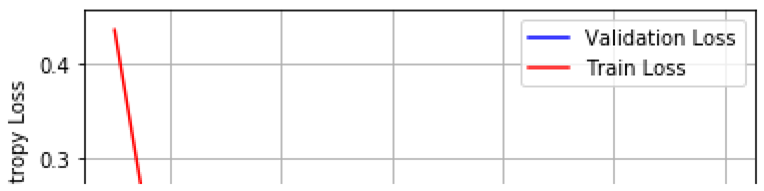
7 LAYER CNN WITHOUT POOL AND DROPOUT

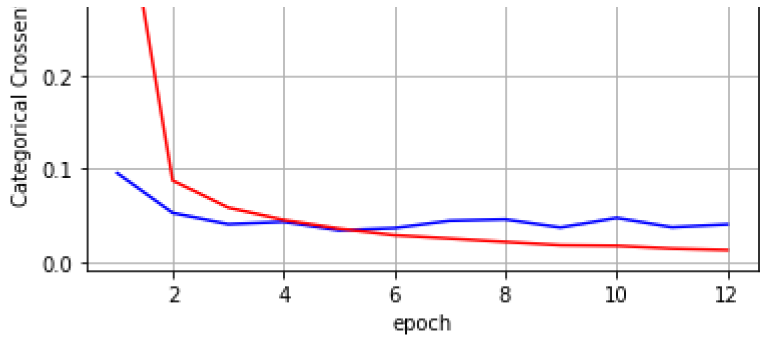
```
model = Sequential()
model.add(Conv2D(64, kernel_size=(7, 7),
                 activation='relu',
                 input_shape=input_shape))
model.add(Conv2D(32, (6, 6), activation='relu'))
model.add(Conv2D(64, (5, 5), activation='relu'))
model.add(Conv2D(64, (4, 4), activation='relu'))
model.add(Conv2D(32, (3, 3), activation='relu'))
model.add(Conv2D(16, (2, 2), activation='relu'))
model.add(Conv2D(8, (2, 2), activation='relu'))
#model.add(MaxPooling2D(pool_size=(2, 2)))
#model.add(Dropout(0.25))
model.add(Flatten())
model.add(Dense(128, activation='relu'))
#model.add(Dropout(0.5))
model.add(Dense(num_classes, activation='softmax'))

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

```
Train on 60000 samples, validate on 10000 samples
Epoch 1/12
60000/60000 [==============================] - 9s 154us/step - loss: 0.4368 - acc: 0.
Epoch 2/12
60000/60000 [==============================] - 5s 90us/step - loss: 0.0873 - acc: 0.9
```

```
Epoch 3/12
60000/60000 [==============================] - 5s 90us/step - loss: 0.0583 - acc: 0.9
Epoch 4/12
60000/60000 [==============================] - 5s 90us/step - loss: 0.0452 - acc: 0.9
Epoch 5/12
60000/60000 [==============================] - 5s 90us/step - loss: 0.0359 - acc: 0.9
Epoch 6/12
60000/60000 [==============================] - 5s 89us/step - loss: 0.0289 - acc: 0.9
Epoch 7/12
60000/60000 [==============================] - 5s 89us/step - loss: 0.0253 - acc: 0.9
Epoch 8/12
60000/60000 [==============================] - 5s 91us/step - loss: 0.0217 - acc: 0.9
Epoch 9/12
60000/60000 [==============================] - 5s 91us/step - loss: 0.0182 - acc: 0.9
Epoch 10/12
60000/60000 [==============================] - 5s 90us/step - loss: 0.0176 - acc: 0.9
Epoch 11/12
60000/60000 [==============================] - 5s 90us/step - loss: 0.0146 - acc: 0.9
Epoch 12/12
60000/60000 [==============================] - 5s 88us/step - loss: 0.0130 - acc: 0.9
Test loss: 0.04047466987816365
Test accuracy: 0.9909
```

```
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))

# print(history.history.keys())
# dict_keys(['val_loss', 'val_acc', 'loss', 'acc'])
# history = model_drop.fit(X_train, Y_train, batch_size=batch_size, epochs=nb_epoch, verbo

# we will get val_loss and val_acc only when you pass the paramter validation_data
# val_loss : validation loss
# val_acc : validation accuracy

# loss : training loss
# acc : train accuracy
# for each key in histrory.histrory we will have a list of length equal to number of epoch

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





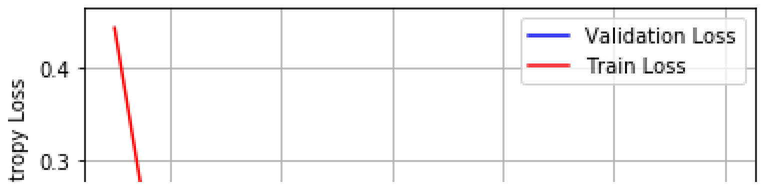
7 LAYER CNN WITH POOL AND without DROPOUT

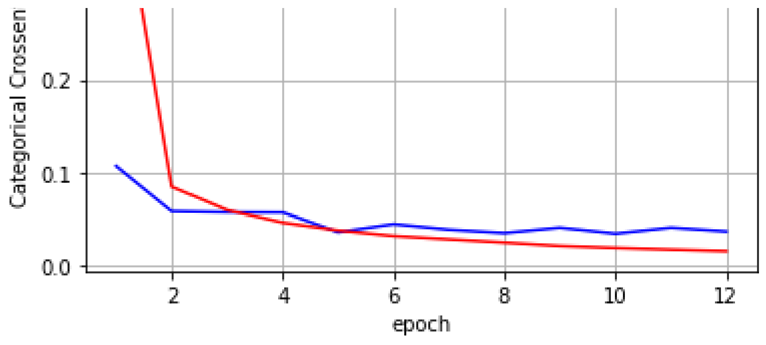
```
model = Sequential()
model.add(Conv2D(64, kernel_size=(7, 7),
                 activation='relu',
                 input_shape=input_shape))
model.add(Conv2D(32, (6, 6), activation='relu'))
model.add(Conv2D(64, (5, 5), activation='relu'))
model.add(Conv2D(64, (4, 4), activation='relu'))
model.add(Conv2D(32, (3, 3), activation='relu'))
model.add(Conv2D(16, (2, 2), activation='relu'))
model.add(Conv2D(8, (2, 2), activation='relu'))
model.add(MaxPooling2D(pool_size=(2, 2)))
#model.add(Dropout(0.25))
model.add(Flatten())
model.add(Dense(128, activation='relu'))
#model.add(Dropout(0.5))
model.add(Dense(num_classes, activation='softmax'))

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

```
Train on 60000 samples, validate on 10000 samples
Epoch 1/12
60000/60000 [==============================] - 9s 156us/step - loss: 0.4436 - acc: 0.
Epoch 2/12
60000/60000 [==============================] - 5s 87us/step - loss: 0.0845 - acc: 0.9
```

```
Epoch 3/12
60000/60000 [==============================] - 5s 89us/step - loss: 0.0593 - acc: 0.9
Epoch 4/12
60000/60000 [==============================] - 5s 88us/step - loss: 0.0457 - acc: 0.9
Epoch 5/12
60000/60000 [==============================] - 5s 88us/step - loss: 0.0373 - acc: 0.9
Epoch 6/12
60000/60000 [==============================] - 5s 89us/step - loss: 0.0314 - acc: 0.9
Epoch 7/12
60000/60000 [==============================] - 5s 88us/step - loss: 0.0278 - acc: 0.9
Epoch 8/12
60000/60000 [==============================] - 5s 89us/step - loss: 0.0243 - acc: 0.9
Epoch 9/12
60000/60000 [==============================] - 5s 88us/step - loss: 0.0207 - acc: 0.9
Epoch 10/12
60000/60000 [==============================] - 5s 87us/step - loss: 0.0185 - acc: 0.9
Epoch 11/12
60000/60000 [==============================] - 5s 88us/step - loss: 0.0168 - acc: 0.9
Epoch 12/12
60000/60000 [==============================] - 5s 87us/step - loss: 0.0151 - acc: 0.9
Test loss: 0.036331293131542 77
Test accuracy: 0.9919
```

```python
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))

# print(history.history.keys())
# dict_keys(['val_loss', 'val_acc', 'loss', 'acc'])
# history = model_drop.fit(X_train, Y_train, batch_size=batch_size, epochs=nb_epoch, verbo

# we will get val_loss and val_acc only when you pass the paramter validation_data
# val_loss : validation loss
# val_acc : validation accuracy

# loss : training loss
# acc : train accuracy
# for each key in histrory.histrory we will have a list of length equal to number of epoch

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





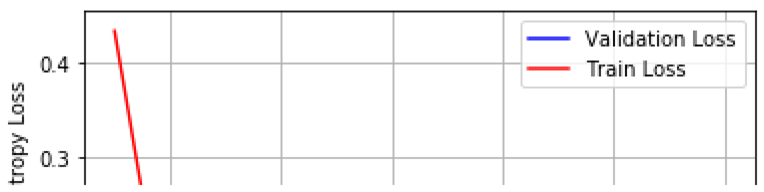
7 LAYER CNN WITH POOL AND with DROPOUT

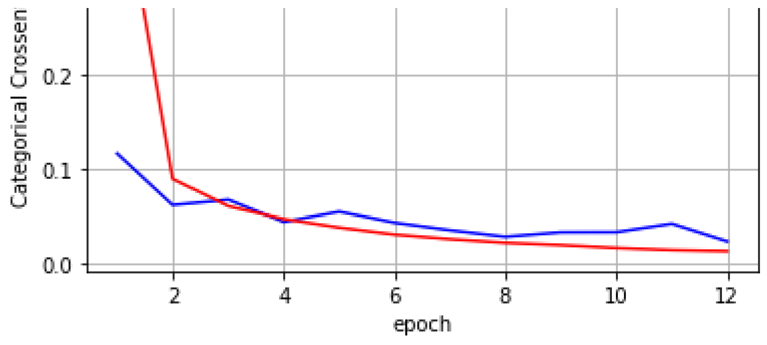
```
model = Sequential()
model.add(Conv2D(64, kernel_size=(7, 7),
                 activation='relu',
                 input_shape=input_shape))
model.add(Conv2D(32, (6, 6), activation='relu'))
model.add(Conv2D(64, (5, 5), activation='relu'))
model.add(Conv2D(64, (4, 4), activation='relu'))
model.add(Conv2D(32, (3, 3), activation='relu'))
model.add(Conv2D(16, (2, 2), activation='relu'))
model.add(Conv2D(8, (2, 2), activation='relu'))
#model.add(MaxPooling2D(pool_size=(2, 2)))
#model.add(Dropout(0.25))
model.add(Flatten())
model.add(Dense(128, activation='relu'))
#model.add(Dropout(0.5))
model.add(Dense(num_classes, activation='softmax'))

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

```
Train on 60000 samples, validate on 10000 samples
Epoch 1/12
60000/60000 [==============================] - 10s 159us/step - loss: 0.4332 - acc: 0
Epoch 2/12
60000/60000 [==============================] - 5s 90us/step - loss: 0.0898 - acc: 0.9
```

```
Epoch 3/12
60000/60000 [==============================] - 5s 89us/step - loss: 0.0611 - acc: 0.9
Epoch 4/12
60000/60000 [==============================] - 5s 89us/step - loss: 0.0474 - acc: 0.9
Epoch 5/12
60000/60000 [==============================] - 5s 89us/step - loss: 0.0384 - acc: 0.9
Epoch 6/12
60000/60000 [==============================] - 5s 89us/step - loss: 0.0311 - acc: 0.9
Epoch 7/12
60000/60000 [==============================] - 5s 87us/step - loss: 0.0263 - acc: 0.9
Epoch 8/12
60000/60000 [==============================] - 5s 87us/step - loss: 0.0225 - acc: 0.9
Epoch 9/12
60000/60000 [==============================] - 5s 89us/step - loss: 0.0201 - acc: 0.9
Epoch 10/12
60000/60000 [==============================] - 5s 88us/step - loss: 0.0170 - acc: 0.9
Epoch 11/12
60000/60000 [==============================] - 5s 89us/step - loss: 0.0148 - acc: 0.9
Epoch 12/12
60000/60000 [==============================] - 5s 88us/step - loss: 0.0137 - acc: 0.9
Test loss: 0.023981265296157062
Test accuracy: 0.9922
```

```python
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))

# print(history.history.keys())
# dict_keys(['val_loss', 'val_acc', 'loss', 'acc'])
# history = model_drop.fit(X_train, Y_train, batch_size=batch_size, epochs=nb_epoch, verbo

# we will get val_loss and val_acc only when you pass the paramter validation_data
# val_loss : validation loss
# val_acc : validation accuracy

# loss : training loss
# acc : train accuracy
# for each key in histrory.histrory we will have a list of length equal to number of epoch

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





Double-click (or enter) to edit

```
# Please compare all your models using Prettytable library
from prettytable import PrettyTable
x = PrettyTable()
x.field_names = ["layer", "type", "log_loss","accuracy"]
```

```
x.add_row(['2_layer','with dropout and max_pool',0.025834757073652508,0.9917])
x.add_row(['3_layer','without dropout and max_pool',0.03626536663422669,0.9913])
x.add_row(['3_layer','without dropout and with max_pool',0.0424302609148956,0.991])
x.add_row(['3_layer','with dropout and with max_pool', 0.02645539062270691,0.9919])
x.add_row(['5_layer','without dropout and  max_pool',0.04818914521079446,0.9911])
x.add_row(['5_layer','without dropout and with max_pool',0.036880395430549655,0.992])
x.add_row(['5_layer','with dropout and with max_pool',0.02116763367687945,0.9924])
x.add_row(['7_layer','without dropout and without max_pool',0.04047466987816365,0.9909])
x.add_row(['7_layer','without dropout and with max_pool',0.03633129313154277,0.9919])
x.add_row(['7_layer','with dropout and with max_pool',0.023981265296157062,0.9922])
```

```
print(x)
```

```
+---------+---------------------------------------+----------------------+----------+
|  layer  |                  type                 |       log_loss       | accuracy |
+---------+---------------------------------------+----------------------+----------+
| 2_layer |       with dropout and max_pool       | 0.025834757073652508 |  0.9917  |
| 3_layer |      without dropout and max_pool     | 0.03626536663422669  |  0.9913  |
| 3_layer |   without dropout and with max_pool   |  0.0424302609148956  |  0.991   |
| 3_layer |     with dropout and with max_pool    | 0.02645539062270691  |  0.9919  |
| 5_layer |     without dropout and  max_pool     | 0.04818914521079446  |  0.9911  |
| 5_layer |   without dropout and with max_pool   | 0.036880395430549655 |  0.992   |
| 5_layer |     with dropout and with max_pool    | 0.02116763367687945  |  0.9924  |
| 7_layer | without dropout and without max_pool  | 0.04047466987816365  |  0.9909  |
| 7_layer |   without dropout and with max_pool   | 0.03633129313154277  |  0.9919  |
| 7_layer |     with dropout and with max_pool    | 0.023981265296157062 |  0.9922  |
+---------+---------------------------------------+----------------------+----------+
```

note

- 3 layer cnn use (5,5),(3,3),(2,2) kernel
- 5 layre cnn use (5,5),(4,4),(3,3),(2,2),(2,2) kernel
- 7 layer cnn use (7,7),(6,6),(5,5),(4,4),(3,3),(2,2),(2,2) kernel