CNN ON MNIST

1. 2 CONVOLUTIONAL LAYERS (MAX POOLING AND DROPOUT INCLUDED)

In [1]:

```
# 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)

model1 = Sequential()
model1.add(Conv2D(32, kernel_size=(3, 3),
                 activation='relu',
                 input_shape=input_shape))
model1.add(Conv2D(64, (3, 3), activation='relu'))
model1.add(MaxPooling2D(pool_size=(2, 2)))
model1.add(Dropout(0.25))
model1.add(Flatten())
model1.add(Dense(128, activation='relu'))
model1.add(Dropout(0.5))
model1.add(Dense(num_classes, activation='softmax'))

model1.compile(loss=keras.losses.categorical_crossentropy,
              optimizer=keras.optimizers.Adadelta(),
              metrics=['accuracy'])

inspect = model1.fit(x_train, y_train,
          batch_size=batch_size,
```

```
          epochs=epochs,
          verbose=1,
          validation_data=(x_test, y_test))
score = model1.evaluate(x_test, y_test, verbose=0)
print('Test loss:', score[0])
print('Test accuracy:', score[1])
```

```
Using TensorFlow backend.
```

```
Downloading data from https://s3.amazonaws.com/img-datasets/mnist.npz
11493376/11490434 [==============================] - 1s 0us/step
x_train shape: (60000, 28, 28, 1)
60000 train samples
10000 test samples
WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/backend/tensorflow_b
ackend.py:66: The name tf.get_default_graph is deprecated. Please use tf.compat.v1.get_de
fault_graph instead.

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

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

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

WARNING:tensorflow:From /usr/local/lib/python3.6/dist-packages/keras/backend/tensorflow_b
ackend.py:3733: calling dropout (from tensorflow.python.ops.nn_ops) with keep_prob is dep
recated 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: T
he 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_b
ackend.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/python/ops/math
_grad.py:1250: add_dispatch_support.<locals>.wrapper (from tensorflow.python.ops.array_op
s) 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
Train on 60000 samples, validate on 10000 samples
Epoch 1/12
60000/60000 [==============================] - 16s 260us/step - loss: 0.2620 - acc: 0.920
3 - val_loss: 0.0547 - val_acc: 0.9829
Epoch 2/12
60000/60000 [==============================] - 9s 144us/step - loss: 0.0875 - acc: 0.9735
- val_loss: 0.0379 - val_acc: 0.9863
Epoch 3/12
60000/60000 [==============================] - 9s 144us/step - loss: 0.0652 - acc: 0.9803
- val_loss: 0.0325 - val_acc: 0.9890
Epoch 4/12
60000/60000 [==============================] - 9s 144us/step - loss: 0.0550 - acc: 0.9834
- val_loss: 0.0351 - val_acc: 0.9884
Epoch 5/12
60000/60000 [==============================] - 9s 144us/step - loss: 0.0478 - acc: 0.9855
- val_loss: 0.0276 - val_acc: 0.9908
Epoch 6/12
60000/60000 [==============================] - 9s 143us/step - loss: 0.0417 - acc: 0.9875
- val_loss: 0.0288 - val_acc: 0.9901
Epoch 7/12
60000/60000 [==============================] - 9s 144us/step - loss: 0.0380 - acc: 0.9881
- val_loss: 0.0320 - val_acc: 0.9895
```

```
- val_loss: 0.0329 - val_acc: 0.9885
Epoch 8/12
60000/60000 [==============================] - 9s 144us/step - loss: 0.0335 - acc: 0.9895
- val_loss: 0.0333 - val_acc: 0.9895
Epoch 9/12
60000/60000 [==============================] - 9s 143us/step - loss: 0.0318 - acc: 0.9900
- val_loss: 0.0267 - val_acc: 0.9924
Epoch 10/12
60000/60000 [==============================] - 9s 144us/step - loss: 0.0306 - acc: 0.9907
- val_loss: 0.0268 - val_acc: 0.9916
Epoch 11/12
60000/60000 [==============================] - 9s 146us/step - loss: 0.0287 - acc: 0.9916
- val_loss: 0.0272 - val_acc: 0.9921
Epoch 12/12
60000/60000 [==============================] - 9s 145us/step - loss: 0.0272 - acc: 0.9915
- val_loss: 0.0267 - val_acc: 0.9922
Test loss: 0.026746683429056065
Test accuracy: 0.9922
```

In [0]:

```
model1.summary()
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_9 (Conv2D)            (None, 26, 26, 32)        320
_________________________________________________________________
conv2d_10 (Conv2D)           (None, 24, 24, 64)        18496
_________________________________________________________________
max_pooling2d_6 (MaxPooling2 (None, 12, 12, 64)        0
_________________________________________________________________
dropout_8 (Dropout)          (None, 12, 12, 64)        0
_________________________________________________________________
flatten_5 (Flatten)          (None, 9216)              0
_________________________________________________________________
dense_9 (Dense)              (None, 128)               1179776
_________________________________________________________________
dropout_9 (Dropout)          (None, 128)               0
_________________________________________________________________
dense_10 (Dense)             (None, 10)                1290
=================================================================
Total params: 1,199,882
Trainable params: 1,199,882
Non-trainable params: 0
_________________________________________________________________
```

In [0]:

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

In [0]:

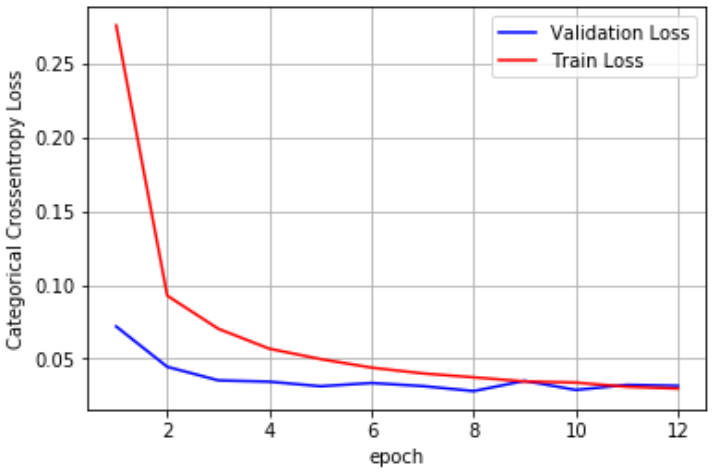
```
def plt_dynamic1(x, vy, ty, ax, colors=['b']):
  ax.plot(x, vy, 'b', label="Validation Accuracy")
  ax.plot(x, ty, 'r', label="Training Accuracy")
  plt.legend()
  plt.grid()
  fig.canvas.draw()
```

In [0]:

```
score = model1.evaluate(x_test, y_test, verbose=0)
```

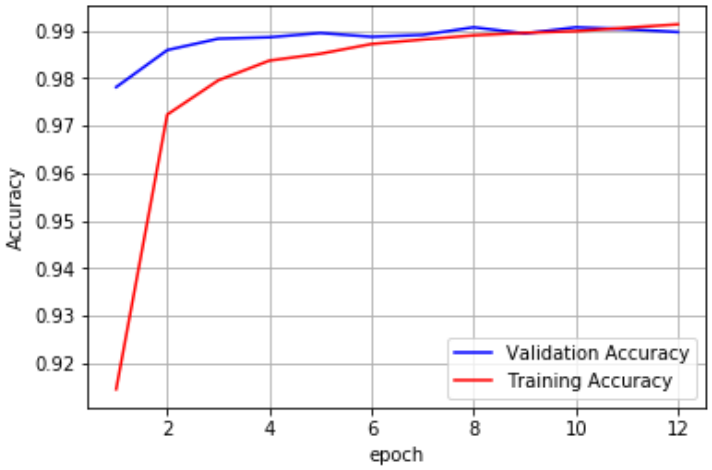
```
print('Test score:', score[0])
print('Test accuracy:', score[1])
fig,ax = plt.subplots(1,1)
ax.set_xlabel('epoch') ; ax.set_ylabel('Categorical Crossentropy Loss')
x = list(range(1,epochs+1))
vl = inspect.history['val_loss']
tl = inspect.history['loss']
plt_dynamic(x, vl, tl, ax)
```

```
Test score: 0.03149389391231671
Test accuracy: 0.9897
```



In [0]:

```
fig,ax = plt.subplots(1,1)
ax.set_xlabel('epoch') ; ax.set_ylabel('Accuracy')
x = list(range(1,epochs+1))
vacc = inspect.history['val_acc']
tacc = inspect.history['acc']
plt_dynamic1(x, vacc, tacc, ax)
```



2. 2 CONVOLUTIONAL LAYERS (MAX POOLING AND BATCH NORMALIZATION)

In [0]:

```
from keras.layers.normalization import BatchNormalization
model2 = Sequential()

model2.add(Conv2D(64, kernel_size=(3, 3),
                 activation='relu',
                 input_shape=input_shape))
model2.add(BatchNormalization())
model2.add(MaxPooling2D(pool_size=(2, 2)))

model2.add(Conv2D(32, (3, 3), activation='relu'))
model2.add(BatchNormalization())
model2.add(MaxPooling2D(pool_size=(2, 2)))
```

```
model2.add(Flatten())
model2.add(Dense(128, activation='relu'))
model2.add(Dropout(0.5))
model2.add(Dense(num_classes, activation='softmax'))

model2.compile(loss=keras.losses.categorical_crossentropy,
              optimizer=keras.optimizers.Adadelta(),
              metrics=['accuracy'])

inspect = model2.fit(x_train, y_train,
          batch_size=batch_size,
          epochs=epochs,
          verbose=1,
          validation_data=(x_test, y_test))
score = model2.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 [==============================] - 5s 90us/step - loss: 0.2421 - acc: 0.9275
- val_loss: 0.0588 - val_acc: 0.9808
Epoch 2/12
60000/60000 [==============================] - 4s 75us/step - loss: 0.0849 - acc: 0.9748
- val_loss: 0.0432 - val_acc: 0.9862
Epoch 3/12
60000/60000 [==============================] - 4s 74us/step - loss: 0.0603 - acc: 0.9819
- val_loss: 0.0310 - val_acc: 0.9898
Epoch 4/12
60000/60000 [==============================] - 4s 75us/step - loss: 0.0499 - acc: 0.9846
- val_loss: 0.0492 - val_acc: 0.9858
Epoch 5/12
60000/60000 [==============================] - 4s 74us/step - loss: 0.0414 - acc: 0.9872
- val_loss: 0.0360 - val_acc: 0.9889
Epoch 6/12
60000/60000 [==============================] - 4s 75us/step - loss: 0.0381 - acc: 0.9882
- val_loss: 0.0285 - val_acc: 0.9913
Epoch 7/12
60000/60000 [==============================] - 4s 75us/step - loss: 0.0323 - acc: 0.9900
- val_loss: 0.0355 - val_acc: 0.9910
Epoch 8/12
60000/60000 [==============================] - 4s 74us/step - loss: 0.0283 - acc: 0.9914
- val_loss: 0.0509 - val_acc: 0.9873
Epoch 9/12
60000/60000 [==============================] - 4s 75us/step - loss: 0.0275 - acc: 0.9919
- val_loss: 0.0264 - val_acc: 0.9922
Epoch 10/12
60000/60000 [==============================] - 4s 75us/step - loss: 0.0248 - acc: 0.9923
- val_loss: 0.0256 - val_acc: 0.9922
Epoch 11/12
60000/60000 [==============================] - 4s 75us/step - loss: 0.0215 - acc: 0.9933
- val_loss: 0.0245 - val_acc: 0.9923
Epoch 12/12
60000/60000 [==============================] - 4s 74us/step - loss: 0.0200 - acc: 0.9938
- val_loss: 0.0235 - val_acc: 0.9936
Test loss: 0.023466705693548782
Test accuracy: 0.9936
```

In [0]:

```
model2.summary()
```

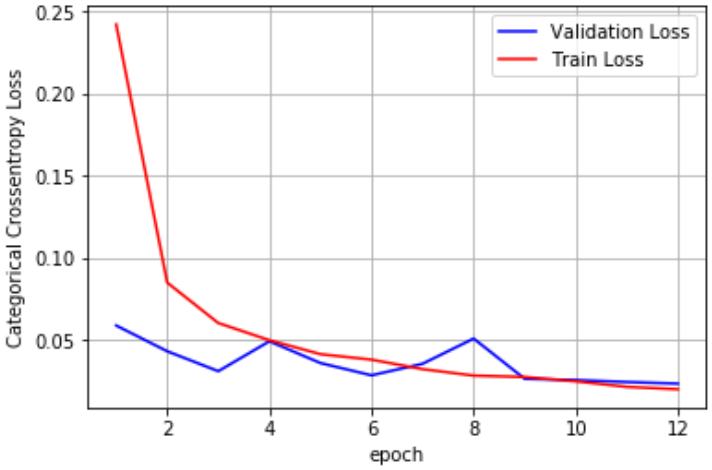
```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_11 (Conv2D)           (None, 26, 26, 64)        640
_________________________________________________________________
batch_normalization_3 (Batch (None, 26, 26, 64)        256
_________________________________________________________________
max_pooling2d_7 (MaxPooling2 (None, 13, 13, 64)        0
_________________________________________________________________
```

```
conv2d_12 (Conv2D)              (None, 11, 11, 32)        18464
_________________________________________________________________
batch_normalization_4 (Batch (None, 11, 11, 32)        128
_________________________________________________________________
max_pooling2d_8 (MaxPooling2 (None, 5, 5, 32)          0
_________________________________________________________________
flatten_6 (Flatten)             (None, 800)               0
_________________________________________________________________
dense_11 (Dense)                (None, 128)               102528
_________________________________________________________________
dropout_10 (Dropout)            (None, 128)               0
_________________________________________________________________
dense_12 (Dense)                (None, 10)                1290
=================================================================
Total params: 123,306
Trainable params: 123,114
Non-trainable params: 192
_________________________________________________________________
```

In [0]:

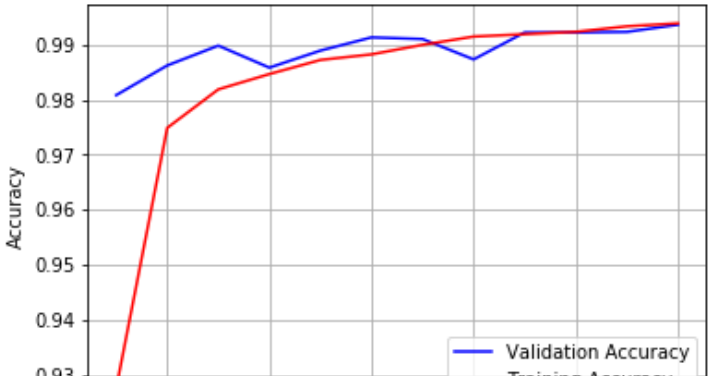
```
score = model2.evaluate(x_test, y_test, verbose=0)
print('Test score:', score[0])
print('Test accuracy:', score[1])
fig,ax = plt.subplots(1,1)
ax.set_xlabel('epoch') ; ax.set_ylabel('Categorical Crossentropy Loss')
x = list(range(1,epochs+1))
vl = inspect.history['val_loss']
tl = inspect.history['loss']
plt_dynamic(x, vl, tl, ax)
```

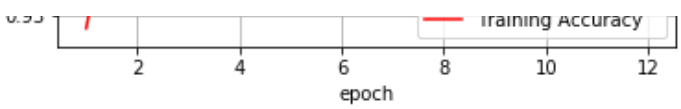
```
Test score: 0.023466705693548782
Test accuracy: 0.9936
```



In [0]:

```
fig,ax = plt.subplots(1,1)
ax.set_xlabel('epoch') ; ax.set_ylabel('Accuracy')
x = list(range(1,epochs+1))
vacc = inspect.history['val_acc']
tacc = inspect.history['acc']
plt_dynamic1(x, vacc, tacc, ax)
```





3. 2 CONVOLUTIONAL LAYERS (MAX POOLING AND BATCH NORMALIZATION AND DROPOUT)

In [0]:

```
from keras.layers.normalization import BatchNormalization
model3 = Sequential()

model3.add(Conv2D(64, kernel_size=(3, 3),
                 activation='relu',
                 input_shape=input_shape))
model3.add(BatchNormalization())
model3.add(MaxPooling2D(pool_size=(2, 2)))
model3.add(Dropout(0.5))

model3.add(Conv2D(32, (3, 3), activation='relu'))
model3.add(BatchNormalization())
model3.add(MaxPooling2D(pool_size=(2, 2)))
model3.add(Dropout(0.5))

model3.add(Flatten())
model3.add(Dense(128, activation='relu'))
model3.add(Dropout(0.5))
model3.add(Dense(num_classes, activation='softmax'))

model3.compile(loss=keras.losses.categorical_crossentropy,
              optimizer=keras.optimizers.Adadelta(),
              metrics=['accuracy'])

inspect = model3.fit(x_train, y_train,
          batch_size=batch_size,
          epochs=epochs,
          verbose=1,
          validation_data=(x_test, y_test))
score = model3.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 [==============================] - 6s 100us/step - loss: 0.6806 - acc: 0.7886
- val_loss: 0.1084 - val_acc: 0.9656
Epoch 2/12
60000/60000 [==============================] - 5s 81us/step - loss: 0.2121 - acc: 0.9370
- val_loss: 0.0637 - val_acc: 0.9802
Epoch 3/12
60000/60000 [==============================] - 5s 81us/step - loss: 0.1523 - acc: 0.9553
- val_loss: 0.0481 - val_acc: 0.9837
Epoch 4/12
60000/60000 [==============================] - 5s 82us/step - loss: 0.1286 - acc: 0.9618
- val_loss: 0.0389 - val_acc: 0.9865
Epoch 5/12
60000/60000 [==============================] - 5s 81us/step - loss: 0.1175 - acc: 0.9653
- val_loss: 0.0375 - val_acc: 0.9886
Epoch 6/12
60000/60000 [==============================] - 5s 81us/step - loss: 0.1036 - acc: 0.9696
- val_loss: 0.0375 - val_acc: 0.9873
Epoch 7/12
60000/60000 [==============================] - 5s 82us/step - loss: 0.1018 - acc: 0.9708
- val_loss: 0.0377 - val_acc: 0.9887
Epoch 8/12
60000/60000 [==============================] - 5s 80us/step - loss: 0.0955 - acc: 0.9722
- val_loss: 0.0374 - val_acc: 0.9886
Epoch 9/12
60000/60000 [==============================] - 5s 81us/step - loss: 0.0871 - acc: 0.9745
- val_loss: 0.0320 - val_acc: 0.9900
Epoch 10/12
60000/60000 [==============================] - 5s 81us/step - loss: 0.0843 - acc: 0.9747
```

```
- val_loss: 0.0288 - val_acc: 0.9903
Epoch 11/12
60000/60000 [==============================] - 5s 81us/step - loss: 0.0805 - acc: 0.9761
- val_loss: 0.0328 - val_acc: 0.9884
Epoch 12/12
60000/60000 [==============================] - 5s 81us/step - loss: 0.0778 - acc: 0.9771
- val_loss: 0.0323 - val_acc: 0.9896
Test loss: 0.032266553132739282
Test accuracy: 0.9896
```

In [0]:

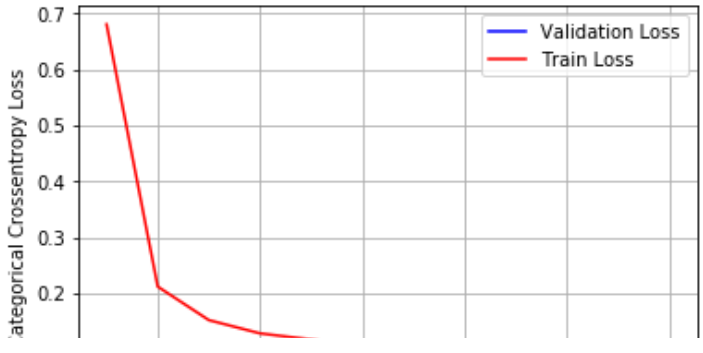
```
model3.summary()
```

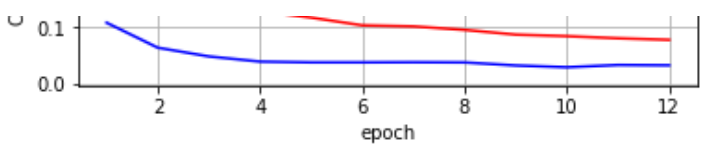
```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_13 (Conv2D)           (None, 26, 26, 64)        640
_________________________________________________________________
batch_normalization_5 (Batch (None, 26, 26, 64)        256
_________________________________________________________________
max_pooling2d_9 (MaxPooling2 (None, 13, 13, 64)        0
_________________________________________________________________
dropout_11 (Dropout)         (None, 13, 13, 64)        0
_________________________________________________________________
conv2d_14 (Conv2D)           (None, 11, 11, 32)        18464
_________________________________________________________________
batch_normalization_6 (Batch (None, 11, 11, 32)        128
_________________________________________________________________
max_pooling2d_10 (MaxPooling (None, 5, 5, 32)          0
_________________________________________________________________
dropout_12 (Dropout)         (None, 5, 5, 32)          0
_________________________________________________________________
flatten_7 (Flatten)          (None, 800)               0
_________________________________________________________________
dense_13 (Dense)             (None, 128)               102528
_________________________________________________________________
dropout_13 (Dropout)         (None, 128)               0
_________________________________________________________________
dense_14 (Dense)             (None, 10)                1290
=================================================================
Total params: 123,306
Trainable params: 123,114
Non-trainable params: 192
_________________________________________________________________
```

In [0]:

```
score = model3.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')
x = list(range(1,epochs+1))
vl = inspect.history['val_loss']
tl = inspect.history['loss']
plt_dynamic(x, vl, tl, ax)
```

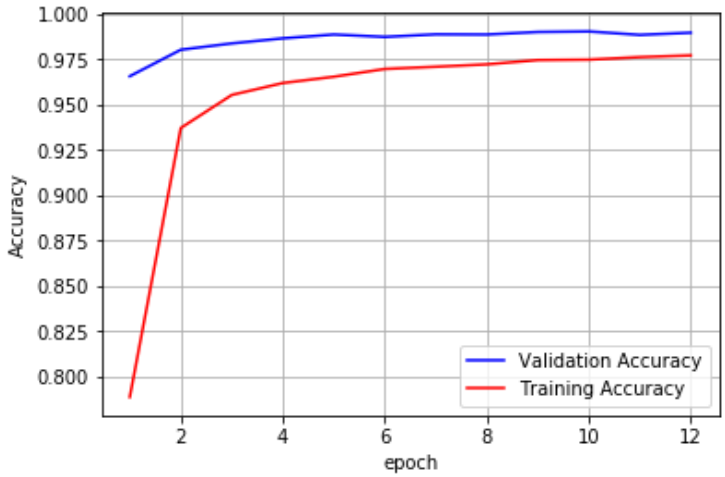
```
Test score: 0.032266553132739282
Test accuracy: 0.9896
```





In [0]:

```
fig,ax = plt.subplots(1,1)
ax.set_xlabel('epoch') ; ax.set_ylabel('Accuracy')
x = list(range(1,epochs+1))
vacc = inspect.history['val_acc']
tacc = inspect.history['acc']
plt_dynamic1(x, vacc, tacc, ax)
```



4. 3 CONVOLUTIONAL LAYERS (MAX POOLING AND BATCH NORMALIZATION 2X2 FILTER)

In [0]:

```
from keras.layers.normalization import BatchNormalization
model4 = Sequential()

model4.add(Conv2D(64, kernel_size=(2, 2),
                 activation='relu',
                 input_shape=input_shape))
model4.add(BatchNormalization())
model4.add(MaxPooling2D(pool_size=(2, 2)))


model4.add(Conv2D(32, (2, 2), activation='relu'))
model4.add(BatchNormalization())
model4.add(MaxPooling2D(pool_size=(2, 2)))

model4.add(Conv2D(32, (2, 2), activation='relu'))
model4.add(BatchNormalization())
model4.add(MaxPooling2D(pool_size=(2, 2)))

model4.add(Flatten())
model4.add(Dense(128, activation='relu'))
model4.add(Dropout(0.5))
model4.add(Dense(num_classes, activation='softmax'))

model4.compile(loss=keras.losses.categorical_crossentropy,
               optimizer=keras.optimizers.Adadelta(),
               metrics=['accuracy'])

inspect = model4.fit(x_train, y_train,
          batch_size=batch_size,
          epochs=epochs,
          verbose=1,
          validation_data=(x_test, y_test))
score = model4.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 108us/step - loss: 0.3744 - acc: 0.8829
- val_loss: 0.1285 - val_acc: 0.9619
Epoch 2/12
60000/60000 [==============================] - 5s 81us/step - loss: 0.1192 - acc: 0.9644
- val_loss: 0.0635 - val_acc: 0.9817
Epoch 3/12
60000/60000 [==============================] - 5s 80us/step - loss: 0.0925 - acc: 0.9725
- val_loss: 0.0627 - val_acc: 0.9794
Epoch 4/12
60000/60000 [==============================] - 5s 81us/step - loss: 0.0728 - acc: 0.9781
- val_loss: 0.0570 - val_acc: 0.9840
Epoch 5/12
60000/60000 [==============================] - 5s 81us/step - loss: 0.0648 - acc: 0.9810
- val_loss: 0.0456 - val_acc: 0.9858
Epoch 6/12
60000/60000 [==============================] - 5s 80us/step - loss: 0.0559 - acc: 0.9830
- val_loss: 0.0432 - val_acc: 0.9867
Epoch 7/12
60000/60000 [==============================] - 5s 80us/step - loss: 0.0508 - acc: 0.9846
- val_loss: 0.0452 - val_acc: 0.9865
Epoch 8/12
60000/60000 [==============================] - 5s 80us/step - loss: 0.0474 - acc: 0.9856
- val_loss: 0.0487 - val_acc: 0.9864
Epoch 9/12
60000/60000 [==============================] - 5s 81us/step - loss: 0.0422 - acc: 0.9867
- val_loss: 0.0476 - val_acc: 0.9864
Epoch 10/12
60000/60000 [==============================] - 5s 80us/step - loss: 0.0422 - acc: 0.9872
- val_loss: 0.0471 - val_acc: 0.9857
Epoch 11/12
60000/60000 [==============================] - 5s 80us/step - loss: 0.0376 - acc: 0.9890
- val_loss: 0.0394 - val_acc: 0.9889
Epoch 12/12
60000/60000 [==============================] - 5s 80us/step - loss: 0.0342 - acc: 0.9895
- val_loss: 0.0450 - val_acc: 0.9874
Test loss: 0.045036793098763704
Test accuracy: 0.9874
```

In [0]:

```
model4.summary()
```

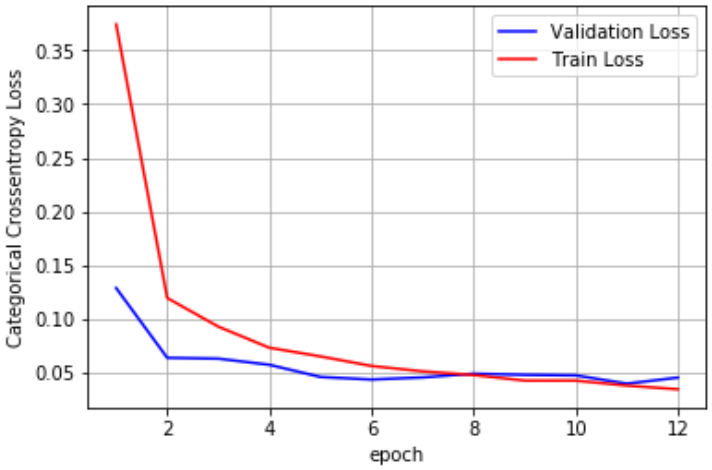
```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_21 (Conv2D)           (None, 27, 27, 64)        320
_________________________________________________________________
batch_normalization_13 (Batc (None, 27, 27, 64)        256
_________________________________________________________________
max_pooling2d_17 (MaxPooling (None, 13, 13, 64)        0
_________________________________________________________________
conv2d_22 (Conv2D)           (None, 12, 12, 32)        8224
_________________________________________________________________
batch_normalization_14 (Batc (None, 12, 12, 32)        128
_________________________________________________________________
max_pooling2d_18 (MaxPooling (None, 6, 6, 32)          0
_________________________________________________________________
conv2d_23 (Conv2D)           (None, 5, 5, 32)          4128
_________________________________________________________________
batch_normalization_15 (Batc (None, 5, 5, 32)          128
_________________________________________________________________
max_pooling2d_19 (MaxPooling (None, 2, 2, 32)          0
_________________________________________________________________
flatten_10 (Flatten)         (None, 128)               0
_________________________________________________________________
dense_19 (Dense)             (None, 128)               16512
_________________________________________________________________
dropout_19 (Dropout)         (None, 128)               0
_________________________________________________________________
dense_20 (Dense)             (None, 10)                1290
```

```
=================================================================
Total params: 30,986
Trainable params: 30,730
Non-trainable params: 256
_________________________________________________________________
```

In [0]:

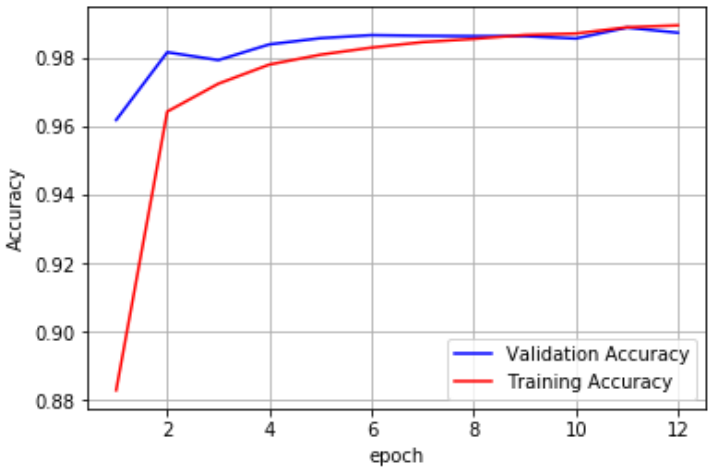
```
score = model4.evaluate(x_test, y_test, verbose=0)
print('Test score:', score[0])
print('Test accuracy:', score[1])
fig,ax = plt.subplots(1,1)
ax.set_xlabel('epoch') ; ax.set_ylabel('Categorical Crossentropy Loss')
x = list(range(1,epochs+1))
vl = inspect.history['val_loss']
tl = inspect.history['loss']
plt_dynamic(x, vl, tl, ax)
```

```
Test score: 0.045036793098763704
Test accuracy: 0.9874
```



In [0]:

```
fig,ax = plt.subplots(1,1)
ax.set_xlabel('epoch') ; ax.set_ylabel('Accuracy')
x = list(range(1,epochs+1))
vacc = inspect.history['val_acc']
tacc = inspect.history['acc']
plt_dynamic1(x, vacc, tacc, ax)
```



5. 3 CONVOLUTIONAL LAYERS (MAX POOLING,DROPOUT AND BATCH NORMALIZATION 5X5 FILTER)

In [0]:

```
from keras.layers.normalization import BatchNormalization
model5 = Sequential()
#1ST
```

```
model5.add(Conv2D(128, kernel_size=(5, 5),
                  activation='relu',
                  input_shape=input_shape))
model5.add(BatchNormalization())
model5.add(MaxPooling2D(pool_size=(2, 2)))
model5.add(Dropout(0.5))

#2ND
model5.add(Conv2D(64, (5, 5), activation='relu'))
model5.add(BatchNormalization())
model5.add(MaxPooling2D(pool_size=(2, 2)))
model5.add(Dropout(0.5))

#3RD

model5.add(Conv2D(32, (3, 3), activation='relu'))
model5.add(BatchNormalization())
model5.add(MaxPooling2D(pool_size=(2, 2)))
model5.add(Dropout(0.5))

model5.add(Flatten())
model5.add(Dense(128, activation='relu'))
model5.add(Dropout(0.5))
model5.add(Dense(num_classes, activation='softmax'))

model5.compile(loss=keras.losses.categorical_crossentropy,
               optimizer=keras.optimizers.Adadelta(),
               metrics=['accuracy'])

inspect = model5.fit(x_train, y_train,
          batch_size=batch_size,
          epochs=epochs,
          verbose=1,
          validation_data=(x_test, y_test))
score = model5.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 151us/step - loss: 0.8208 - acc: 0.7304
- val_loss: 0.0687 - val_acc: 0.9793
Epoch 2/12
60000/60000 [==============================] - 7s 118us/step - loss: 0.2279 - acc: 0.9324
- val_loss: 0.0879 - val_acc: 0.9726
Epoch 3/12
60000/60000 [==============================] - 7s 119us/step - loss: 0.1650 - acc: 0.9520
- val_loss: 0.0400 - val_acc: 0.9878
Epoch 4/12
60000/60000 [==============================] - 7s 118us/step - loss: 0.1426 - acc: 0.9598
- val_loss: 0.0365 - val_acc: 0.9892
Epoch 5/12
60000/60000 [==============================] - 7s 119us/step - loss: 0.1218 - acc: 0.9652
- val_loss: 0.0289 - val_acc: 0.9903
Epoch 6/12
60000/60000 [==============================] - 7s 119us/step - loss: 0.1123 - acc: 0.9684
- val_loss: 0.0273 - val_acc: 0.9915
Epoch 7/12
60000/60000 [==============================] - 7s 118us/step - loss: 0.1044 - acc: 0.9715
- val_loss: 0.0275 - val_acc: 0.9918
Epoch 8/12
60000/60000 [==============================] - 7s 119us/step - loss: 0.0985 - acc: 0.9728
- val_loss: 0.0262 - val_acc: 0.9909
Epoch 9/12
60000/60000 [==============================] - 7s 118us/step - loss: 0.0961 - acc: 0.9734
- val_loss: 0.0236 - val_acc: 0.9935
Epoch 10/12
60000/60000 [==============================] - 7s 118us/step - loss: 0.0901 - acc: 0.9751
- val_loss: 0.0287 - val_acc: 0.9911
Epoch 11/12
60000/60000 [==============================] - 7s 118us/step - loss: 0.0831 - acc: 0.9764
- val_loss: 0.0231 - val_acc: 0.9924
```

```
Epoch 12/12
60000/60000 [==============================] - 7s 118us/step - loss: 0.0846 - acc: 0.9765
- val_loss: 0.0235 - val_acc: 0.9927
Test loss: 0.023486822005478462
Test accuracy: 0.9927
```

In [0]:

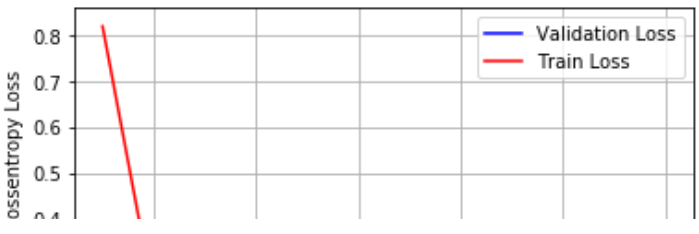
```
model5.summary()
```

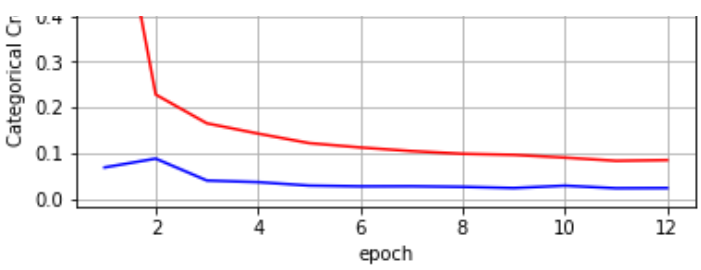
```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_24 (Conv2D)           (None, 24, 24, 128)       3328
_________________________________________________________________
batch_normalization_16 (Batc (None, 24, 24, 128)       512
_________________________________________________________________
max_pooling2d_20 (MaxPooling (None, 12, 12, 128)       0
_________________________________________________________________
dropout_20 (Dropout)         (None, 12, 12, 128)       0
_________________________________________________________________
conv2d_25 (Conv2D)           (None, 8, 8, 64)          204864
_________________________________________________________________
batch_normalization_17 (Batc (None, 8, 8, 64)          256
_________________________________________________________________
max_pooling2d_21 (MaxPooling (None, 4, 4, 64)          0
_________________________________________________________________
dropout_21 (Dropout)         (None, 4, 4, 64)          0
_________________________________________________________________
conv2d_26 (Conv2D)           (None, 2, 2, 32)          18464
_________________________________________________________________
batch_normalization_18 (Batc (None, 2, 2, 32)          128
_________________________________________________________________
max_pooling2d_22 (MaxPooling (None, 1, 1, 32)          0
_________________________________________________________________
dropout_22 (Dropout)         (None, 1, 1, 32)          0
_________________________________________________________________
flatten_11 (Flatten)         (None, 32)                0
_________________________________________________________________
dense_21 (Dense)             (None, 128)               4224
_________________________________________________________________
dropout_23 (Dropout)         (None, 128)               0
_________________________________________________________________
dense_22 (Dense)             (None, 10)                1290
=================================================================
Total params: 233,066
Trainable params: 232,618
Non-trainable params: 448
_________________________________________________________________
```

In [0]:

```
score = model5.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')
x = list(range(1,epochs+1))
vl = inspect.history['val_loss']
tl = inspect.history['loss']
plt_dynamic(x, vl, tl, ax)
```

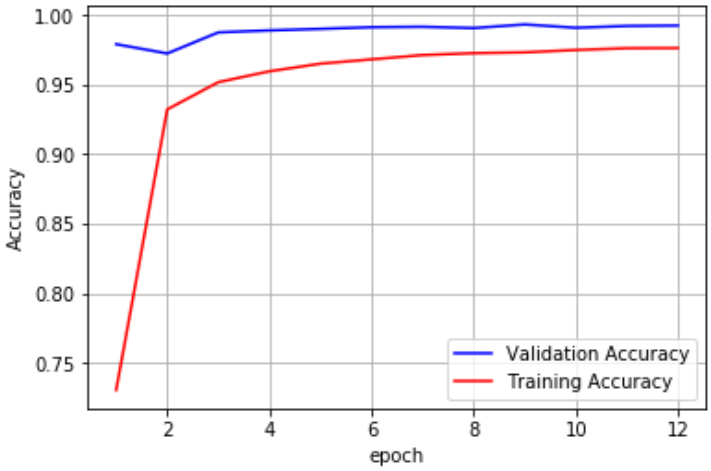
```
Test score: 0.023486822005478462
Test accuracy: 0.9927
```





In [0]:

```
fig,ax = plt.subplots(1,1)
ax.set_xlabel('epoch') ; ax.set_ylabel('Accuracy')
x = list(range(1,epochs+1))
vacc = inspect.history['val_acc']
tacc = inspect.history['acc']
plt_dynamic1(x, vacc, tacc, ax)
```



6. 3 CONVOLUTIONAL LAYERS (MAX POOLING AND BATCH NORMALIZATION 7X7 AND 5X5 FILTER)

In [0]:

```
from keras.layers.normalization import BatchNormalization
model6 = Sequential()
#1ST
model6.add(Conv2D(128, kernel_size=(7, 7),
                 activation='relu',
                 input_shape=input_shape))
model6.add(BatchNormalization())
model6.add(MaxPooling2D(pool_size=(2, 2)))


#2ND
model6.add(Conv2D(64, (5, 5), activation='relu'))
model6.add(BatchNormalization())
model6.add(MaxPooling2D(pool_size=(2, 2)))


#3RD

model6.add(Conv2D(32, (3, 3), activation='relu'))
model6.add(BatchNormalization())
#model.add(MaxPooling2D(pool_size=(2, 2)))


model6.add(Flatten())
model6.add(Dense(128, activation='relu'))
model6.add(Dense(64, activation='relu'))
model6.add(Dense(num_classes, activation='softmax'))

model6.compile(loss=keras.losses.categorical_crossentropy,
              optimizer=keras.optimizers.Adadelta(),
              metrics=['accuracy'])
```

```
inspect = model6.fit(x_train, y_train,
          batch_size=batch_size,
          epochs=epochs,
          verbose=1,
          validation_data=(x_test, y_test))
score = model6.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: 0.1286 - acc: 0.9657
- val_loss: 0.0610 - val_acc: 0.9820
Epoch 2/12
60000/60000 [==============================] - 6s 105us/step - loss: 0.0386 - acc: 0.9878
- val_loss: 0.0315 - val_acc: 0.9899
Epoch 3/12
60000/60000 [==============================] - 6s 107us/step - loss: 0.0262 - acc: 0.9913
- val_loss: 0.0456 - val_acc: 0.9879
Epoch 4/12
60000/60000 [==============================] - 6s 104us/step - loss: 0.0193 - acc: 0.9937
- val_loss: 0.0295 - val_acc: 0.9907
Epoch 5/12
60000/60000 [==============================] - 6s 105us/step - loss: 0.0132 - acc: 0.9957
- val_loss: 0.0390 - val_acc: 0.9887
Epoch 6/12
60000/60000 [==============================] - 6s 105us/step - loss: 0.0101 - acc: 0.9970
- val_loss: 0.0271 - val_acc: 0.9916
Epoch 7/12
60000/60000 [==============================] - 6s 105us/step - loss: 0.0077 - acc: 0.9975
- val_loss: 0.0253 - val_acc: 0.9928
Epoch 8/12
60000/60000 [==============================] - 6s 104us/step - loss: 0.0058 - acc: 0.9980
- val_loss: 0.0354 - val_acc: 0.9912
Epoch 9/12
60000/60000 [==============================] - 6s 105us/step - loss: 0.0049 - acc: 0.9984
- val_loss: 0.0295 - val_acc: 0.9923
Epoch 10/12
60000/60000 [==============================] - 6s 104us/step - loss: 0.0033 - acc: 0.9987
- val_loss: 0.0359 - val_acc: 0.9920
Epoch 11/12
60000/60000 [==============================] - 6s 104us/step - loss: 0.0033 - acc: 0.9989
- val_loss: 0.0303 - val_acc: 0.9931
Epoch 12/12
60000/60000 [==============================] - 6s 104us/step - loss: 0.0027 - acc: 0.9990
- val_loss: 0.0332 - val_acc: 0.9927
Test loss: 0.03316479856713909
Test accuracy: 0.9927
```

In [0]:

```
model6.summary()
```

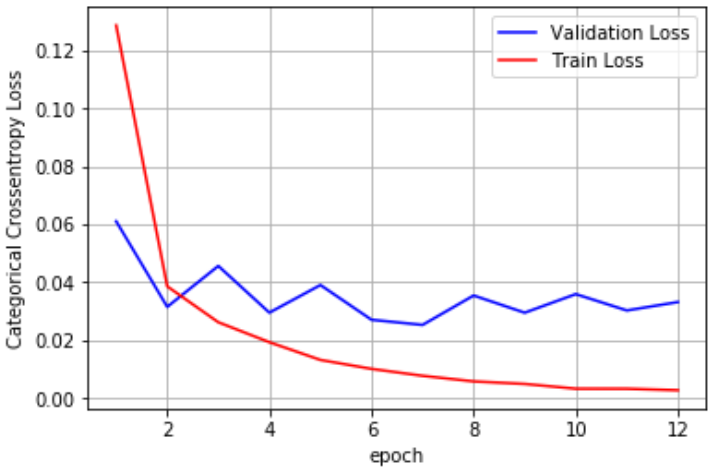
```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_33 (Conv2D)           (None, 22, 22, 128)       6400
_________________________________________________________________
batch_normalization_25 (Batc (None, 22, 22, 128)       512
_________________________________________________________________
max_pooling2d_27 (MaxPooling (None, 11, 11, 128)       0
_________________________________________________________________
conv2d_34 (Conv2D)           (None, 7, 7, 64)          204864
_________________________________________________________________
batch_normalization_26 (Batc (None, 7, 7, 64)          256
_________________________________________________________________
max_pooling2d_28 (MaxPooling (None, 3, 3, 64)          0
_________________________________________________________________
conv2d_35 (Conv2D)           (None, 1, 1, 32)          18464
_________________________________________________________________
batch_normalization_27 (Batc (None, 1, 1, 32)          128
```

```
_________________________________________________________________
flatten_8 (Flatten)          (None, 32)                0
_________________________________________________________________
dense_15 (Dense)             (None, 128)               4224
_________________________________________________________________
dense_16 (Dense)             (None, 64)                8256
_________________________________________________________________
dense_17 (Dense)             (None, 10)                650
=================================================================
Total params: 243,754
Trainable params: 243,306
Non-trainable params: 448
_________________________________________________________________
```

In [0]:

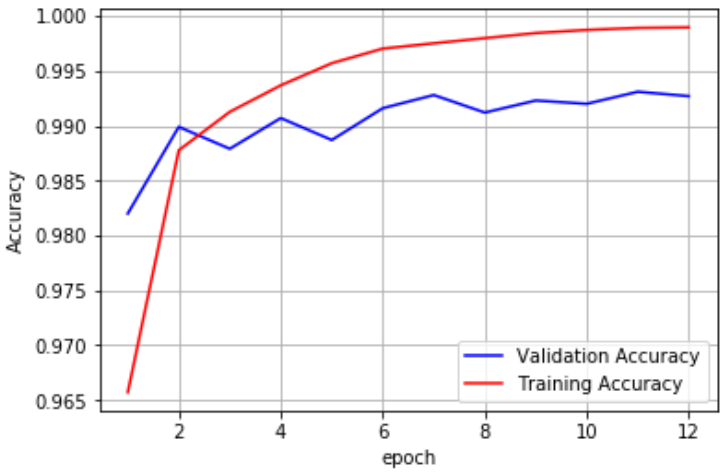
```
score = model6.evaluate(x_test, y_test, verbose=0)
print('Test score:', score[0])
print('Test accuracy:', score[1])
fig,ax = plt.subplots(1,1)
ax.set_xlabel('epoch') ; ax.set_ylabel('Categorical Crossentropy Loss')
x = list(range(1,epochs+1))
vl = inspect.history['val_loss']
tl = inspect.history['loss']
plt_dynamic(x, vl, tl, ax)
```

```
Test score: 0.03316479856713909
Test accuracy: 0.9927
```



In [0]:

```
fig,ax = plt.subplots(1,1)
ax.set_xlabel('epoch') ; ax.set_ylabel('Accuracy')
x = list(range(1,epochs+1))
vacc = inspect.history['val_acc']
tacc = inspect.history['acc']
plt_dynamic1(x, vacc, tacc, ax)
```



7. 5 CONVOLUTIONAL LAYERS (MAX POOLING AND BATCH NORMALIZATION 3X3 FILTER)

In [0]:

```
from keras.layers.normalization import BatchNormalization
model7 = Sequential()
#1ST
model7.add(Conv2D(256, kernel_size=(3, 3),
                 activation='relu',
                 input_shape=input_shape,padding="same"))
model7.add(BatchNormalization())
model7.add(MaxPooling2D(pool_size=(2, 2)))


#2ND
model7.add(Conv2D(128, (3, 3), activation='relu',padding="same"))
model7.add(BatchNormalization())
model7.add(MaxPooling2D(pool_size=(2, 2)))


#3RD
model7.add(Conv2D(64, (3, 3), activation='relu',padding="same"))
model7.add(BatchNormalization())
model7.add(MaxPooling2D(pool_size=(2, 2)))

#4TH
model7.add(Conv2D(32, (3, 3), activation='relu',padding="same"))
model7.add(BatchNormalization())
model7.add(MaxPooling2D(pool_size=(2, 2)))

#5TH
model7.add(Conv2D(16, (3, 3), activation='relu',padding="same"))
model7.add(BatchNormalization())
#model.add(MaxPooling2D(pool_size=(2, 2)))

model7.add(Flatten())
model7.add(Dense(32, activation='relu'))

model7.add(Dense(num_classes, activation='softmax'))

model7.compile(loss=keras.losses.categorical_crossentropy,
              optimizer=keras.optimizers.Adadelta(),
              metrics=['accuracy'])

inspect = model7.fit(x_train, y_train,
          batch_size=batch_size,
          epochs=epochs,
          verbose=1,
          validation_data=(x_test, y_test))
score = model7.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 [==============================] - 18s 294us/step - loss: 0.2058 - acc: 0.951
2 - val_loss: 0.0864 - val_acc: 0.9748
Epoch 2/12
60000/60000 [==============================] - 15s 247us/step - loss: 0.0435 - acc: 0.987
3 - val_loss: 0.0550 - val_acc: 0.9841
Epoch 3/12
60000/60000 [==============================] - 15s 247us/step - loss: 0.0289 - acc: 0.991
5 - val_loss: 0.0323 - val_acc: 0.9903
Epoch 4/12
60000/60000 [==============================] - 15s 247us/step - loss: 0.0202 - acc: 0.993
7 - val_loss: 0.0297 - val_acc: 0.9907
Epoch 5/12
60000/60000 [==============================] - 15s 246us/step - loss: 0.0139 - acc: 0.996
0 - val_loss: 0.1061 - val_acc: 0.9695
Epoch 6/12
60000/60000 [==============================] - 15s 246us/step - loss: 0.0113 - acc: 0.996
5 - val_loss: 0.0327 - val_acc: 0.9908
```

```
Epoch 7/12
60000/60000 [==============================] - 15s 246us/step - loss: 0.0079 - acc: 0.997
7 - val_loss: 0.0266 - val_acc: 0.9933
Epoch 8/12
60000/60000 [==============================] - 15s 247us/step - loss: 0.0060 - acc: 0.998
3 - val_loss: 0.0270 - val_acc: 0.9923
Epoch 9/12
60000/60000 [==============================] - 15s 246us/step - loss: 0.0057 - acc: 0.998
0 - val_loss: 0.0377 - val_acc: 0.9900
Epoch 10/12
60000/60000 [==============================] - 15s 246us/step - loss: 0.0031 - acc: 0.999
2 - val_loss: 0.0342 - val_acc: 0.9906
Epoch 11/12
60000/60000 [==============================] - 15s 246us/step - loss: 0.0027 - acc: 0.999
3 - val_loss: 0.0361 - val_acc: 0.9908
Epoch 12/12
60000/60000 [==============================] - 15s 246us/step - loss: 0.0016 - acc: 0.999
6 - val_loss: 0.0321 - val_acc: 0.9913
Test loss: 0.032069397589693835
Test accuracy: 0.9913
```

In [0]:

```
model7.summary()
```

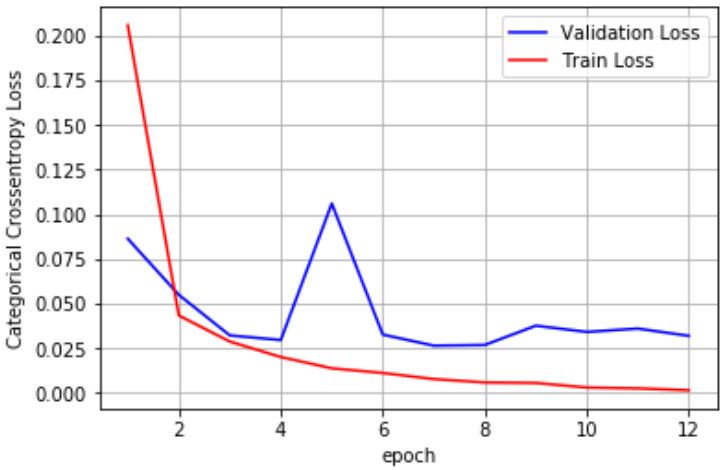
```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_30 (Conv2D)           (None, 28, 28, 256)       2560
_________________________________________________________________
batch_normalization_22 (Batc (None, 28, 28, 256)       1024
_________________________________________________________________
max_pooling2d_25 (MaxPooling (None, 14, 14, 256)       0
_________________________________________________________________
conv2d_31 (Conv2D)           (None, 14, 14, 128)       295040
_________________________________________________________________
batch_normalization_23 (Batc (None, 14, 14, 128)       512
_________________________________________________________________
max_pooling2d_26 (MaxPooling (None, 7, 7, 128)         0
_________________________________________________________________
conv2d_32 (Conv2D)           (None, 7, 7, 64)          73792
_________________________________________________________________
batch_normalization_24 (Batc (None, 7, 7, 64)          256
_________________________________________________________________
max_pooling2d_27 (MaxPooling (None, 3, 3, 64)          0
_________________________________________________________________
conv2d_33 (Conv2D)           (None, 3, 3, 32)          18464
_________________________________________________________________
batch_normalization_25 (Batc (None, 3, 3, 32)          128
_________________________________________________________________
max_pooling2d_28 (MaxPooling (None, 1, 1, 32)          0
_________________________________________________________________
conv2d_34 (Conv2D)           (None, 1, 1, 16)          4624
_________________________________________________________________
batch_normalization_26 (Batc (None, 1, 1, 16)          64
_________________________________________________________________
flatten_13 (Flatten)         (None, 16)                0
_________________________________________________________________
dense_26 (Dense)             (None, 32)                544
_________________________________________________________________
dense_27 (Dense)             (None, 10)                330
=================================================================
Total params: 397,338
Trainable params: 396,346
Non-trainable params: 992
_________________________________________________________________
```

In [0]:

```
score = model7.evaluate(x_test, y_test, verbose=0)
print('Test score:', score[0])
```

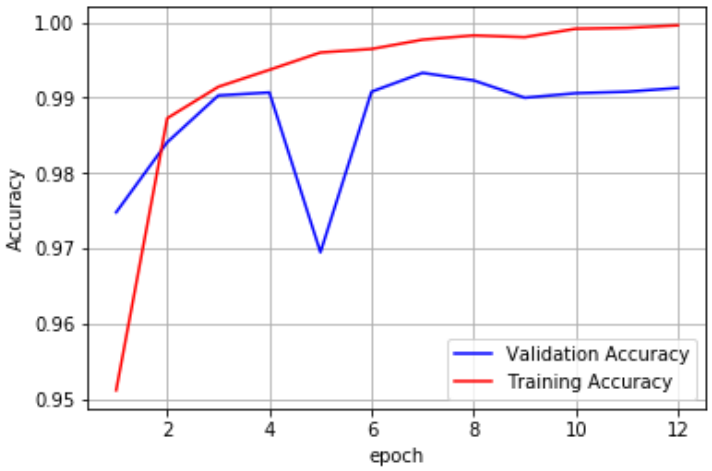
```
print('Test accuracy:', score[1])
fig,ax = plt.subplots(1,1)
ax.set_xlabel('epoch') ; ax.set_ylabel('Categorical Crossentropy Loss')
x = list(range(1,epochs+1))
vl = inspect.history['val_loss']
tl = inspect.history['loss']
plt_dynamic(x, vl, tl, ax)
```

```
Test score: 0.032069397589693835
Test accuracy: 0.9913
```



In [0]:

```
fig,ax = plt.subplots(1,1)
ax.set_xlabel('epoch') ; ax.set_ylabel('Accuracy')
x = list(range(1,epochs+1))
vacc = inspect.history['val_acc']
tacc = inspect.history['acc']
plt_dynamic1(x, vacc, tacc, ax)
```



8. 5 CONVOLUTIONAL LAYERS (MAX POOLING,DROPOUT AND BATCH NORMALIZATION 3X3 FILTER)

In [0]:

```
from keras.layers.normalization import BatchNormalization
model8 = Sequential()
#1ST
model8.add(Conv2D(256, kernel_size=(3, 3),
                 activation='relu',
                 input_shape=input_shape,padding="same"))
model8.add(BatchNormalization())
model8.add(MaxPooling2D(pool_size=(2, 2)))
model8.add(Dropout(0.5))


#2ND
model8.add(Conv2D(128, (3, 3), activation='relu',padding="same"))
```

```
model8.add(BatchNormalization())
model8.add(MaxPooling2D(pool_size=(2, 2)))
model8.add(Dropout(0.5))


#3RD
model8.add(Conv2D(64, (3, 3), activation='relu',padding="same"))
model8.add(BatchNormalization())
model8.add(MaxPooling2D(pool_size=(2, 2)))
model8.add(Dropout(0.5))

#4TH
model8.add(Conv2D(32, (3, 3), activation='relu',padding="same"))
model8.add(BatchNormalization())
model8.add(MaxPooling2D(pool_size=(2, 2)))
model8.add(Dropout(0.5))

#5TH
model8.add(Conv2D(16, (3, 3), activation='relu',padding="same"))
model8.add(BatchNormalization())
#model.add(MaxPooling2D(pool_size=(2, 2)))
model8.add(Dropout(0.5))

model8.add(Flatten())
model8.add(Dense(32, activation='relu'))

model8.add(Dense(num_classes, activation='softmax'))

model8.compile(loss=keras.losses.categorical_crossentropy,
              optimizer=keras.optimizers.Adadelta(),
              metrics=['accuracy'])

inspect = model8.fit(x_train, y_train,
          batch_size=batch_size,
          epochs=epochs,
          verbose=1,
          validation_data=(x_test, y_test))
score = model8.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 [==============================] - 19s 321us/step - loss: 1.5369 - acc: 0.440
7 - val_loss: 0.4345 - val_acc: 0.9056
Epoch 2/12
60000/60000 [==============================] - 17s 275us/step - loss: 0.6787 - acc: 0.756
6 - val_loss: 0.1479 - val_acc: 0.9698
Epoch 3/12
60000/60000 [==============================] - 16s 275us/step - loss: 0.4721 - acc: 0.837
4 - val_loss: 0.1065 - val_acc: 0.9716
Epoch 4/12
60000/60000 [==============================] - 16s 274us/step - loss: 0.3915 - acc: 0.869
5 - val_loss: 0.0564 - val_acc: 0.9841
Epoch 5/12
60000/60000 [==============================] - 16s 275us/step - loss: 0.3410 - acc: 0.886
6 - val_loss: 0.0594 - val_acc: 0.9841
Epoch 6/12
60000/60000 [==============================] - 16s 275us/step - loss: 0.3148 - acc: 0.894
9 - val_loss: 0.0508 - val_acc: 0.9868
Epoch 7/12
60000/60000 [==============================] - 16s 274us/step - loss: 0.2894 - acc: 0.901
2 - val_loss: 0.0454 - val_acc: 0.9888
Epoch 8/12
60000/60000 [==============================] - 16s 274us/step - loss: 0.2782 - acc: 0.905
6 - val_loss: 0.0442 - val_acc: 0.9890
Epoch 9/12
60000/60000 [==============================] - 16s 273us/step - loss: 0.2633 - acc: 0.912
4 - val_loss: 0.0436 - val_acc: 0.9891
Epoch 10/12
60000/60000 [==============================] - 17s 276us/step - loss: 0.2566 - acc: 0.914
4 - val_loss: 0.0411 - val_acc: 0.9896
```

```
Epoch 11/12
60000/60000 [==============================] - 16s 275us/step - loss: 0.2422 - acc: 0.919
0 - val_loss: 0.0385 - val_acc: 0.9896
Epoch 12/12
60000/60000 [==============================] - 16s 273us/step - loss: 0.2344 - acc: 0.920
5 - val_loss: 0.0385 - val_acc: 0.9900
Test loss: 0.0385118981421052
Test accuracy: 0.99
```

In [0]:

```
model8.summary()
```

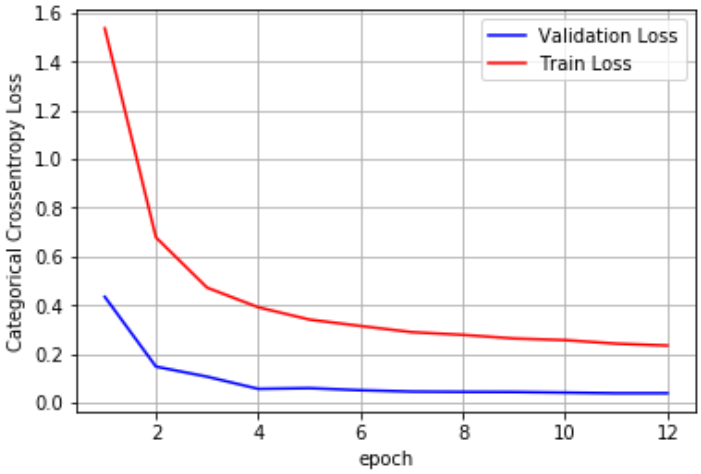
```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_35 (Conv2D)           (None, 28, 28, 256)       2560
_________________________________________________________________
batch_normalization_27 (Batc (None, 28, 28, 256)       1024
_________________________________________________________________
max_pooling2d_29 (MaxPooling (None, 14, 14, 256)       0
_________________________________________________________________
dropout_24 (Dropout)         (None, 14, 14, 256)       0
_________________________________________________________________
conv2d_36 (Conv2D)           (None, 14, 14, 128)       295040
_________________________________________________________________
batch_normalization_28 (Batc (None, 14, 14, 128)       512
_________________________________________________________________
max_pooling2d_30 (MaxPooling (None, 7, 7, 128)         0
_________________________________________________________________
dropout_25 (Dropout)         (None, 7, 7, 128)         0
_________________________________________________________________
conv2d_37 (Conv2D)           (None, 7, 7, 64)          73792
_________________________________________________________________
batch_normalization_29 (Batc (None, 7, 7, 64)          256
_________________________________________________________________
max_pooling2d_31 (MaxPooling (None, 3, 3, 64)          0
_________________________________________________________________
dropout_26 (Dropout)         (None, 3, 3, 64)          0
_________________________________________________________________
conv2d_38 (Conv2D)           (None, 3, 3, 32)          18464
_________________________________________________________________
batch_normalization_30 (Batc (None, 3, 3, 32)          128
_________________________________________________________________
max_pooling2d_32 (MaxPooling (None, 1, 1, 32)          0
_________________________________________________________________
dropout_27 (Dropout)         (None, 1, 1, 32)          0
_________________________________________________________________
conv2d_39 (Conv2D)           (None, 1, 1, 16)          4624
_________________________________________________________________
batch_normalization_31 (Batc (None, 1, 1, 16)          64
_________________________________________________________________
dropout_28 (Dropout)         (None, 1, 1, 16)          0
_________________________________________________________________
flatten_14 (Flatten)         (None, 16)                0
_________________________________________________________________
dense_28 (Dense)             (None, 32)                544
_________________________________________________________________
dense_29 (Dense)             (None, 10)                330
=================================================================
Total params: 397,338
Trainable params: 396,346
Non-trainable params: 992
_________________________________________________________________
```

In [0]:

```
score = model8.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')
```

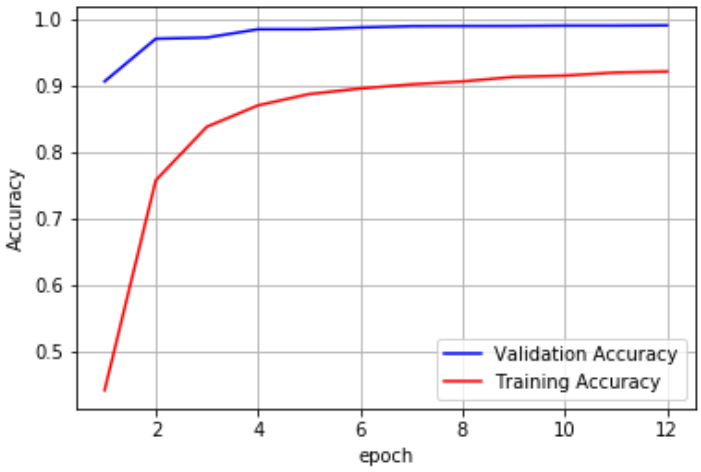
```
x = list(range(1,epochs+1))
vl = inspect.history['val_loss']
tl = inspect.history['loss']
plt_dynamic(x, vl, tl, ax)
```

```
Test score: 0.0385118981421052
Test accuracy: 0.99
```



In [0]:

```
fig,ax = plt.subplots(1,1)
ax.set_xlabel('epoch') ; ax.set_ylabel('Accuracy')
x = list(range(1,epochs+1))
vacc = inspect.history['val_acc']
tacc = inspect.history['acc']
plt_dynamic1(x, vacc, tacc, ax)
```



9. 7 CONVOLUTIONAL LAYERS (MAX POOLING,DROPOUT AND BATCH NORMALIZATION 3X3 FILTER)

In [0]:

```
from keras.layers.normalization import BatchNormalization
model9 = Sequential()
#1ST
model9.add(Conv2D(256, kernel_size=(3, 3),
                 activation='relu',
                 input_shape=input_shape,padding="same"))
model9.add(BatchNormalization())
model9.add(MaxPooling2D(pool_size=(2, 2)))
model9.add(Dropout(0.2))


#2ND
model9.add(Conv2D(128, (3, 3), activation='relu',padding="same"))
model9.add(BatchNormalization())
model9.add(MaxPooling2D(pool_size=(2, 2)))
model9.add(Dropout(0.2))
```

```
#3RD
model9.add(Conv2D(64, (3, 3), activation='relu',padding="same"))
model9.add(BatchNormalization())
model9.add(MaxPooling2D(pool_size=(2, 2)))
model9.add(Dropout(0.2))

#4TH
model9.add(Conv2D(64, (3, 3), activation='relu',padding="same"))
model9.add(BatchNormalization())
model9.add(MaxPooling2D(pool_size=(2, 2)))
model9.add(Dropout(0.2))

#5TH
model9.add(Conv2D(32, (3, 3), activation='relu',padding="same"))
model9.add(BatchNormalization())
#model.add(MaxPooling2D(pool_size=(2, 2)))
model9.add(Dropout(0.2))

#6TH
model9.add(Conv2D(32, (3, 3), activation='relu',padding="same"))
model9.add(BatchNormalization())
#model.add(MaxPooling2D(pool_size=(2, 2)))
model9.add(Dropout(0.2))

#7TH
model9.add(Conv2D(16, (3, 3), activation='relu',padding="same"))
model9.add(BatchNormalization())
#model.add(MaxPooling2D(pool_size=(2, 2)))
model9.add(Dropout(0.2))

model9.add(Flatten())
model9.add(Dense(32, activation='relu'))

model9.add(Dense(num_classes, activation='softmax'))

model9.compile(loss=keras.losses.categorical_crossentropy,
              optimizer=keras.optimizers.Adadelta(),
              metrics=['accuracy'])

inspect = model9.fit(x_train, y_train,
          batch_size=batch_size,
          epochs=epochs,
          verbose=1,
          validation_data=(x_test, y_test))
score = model9.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 [==============================] - 21s 347us/step - loss: 0.6060 - acc: 0.811
4 - val_loss: 0.0880 - val_acc: 0.9770
Epoch 2/12
60000/60000 [==============================] - 17s 288us/step - loss: 0.1467 - acc: 0.963
4 - val_loss: 0.0659 - val_acc: 0.9816
Epoch 3/12
60000/60000 [==============================] - 18s 295us/step - loss: 0.1015 - acc: 0.975
3 - val_loss: 0.0462 - val_acc: 0.9891
Epoch 4/12
60000/60000 [==============================] - 18s 296us/step - loss: 0.0836 - acc: 0.979
8 - val_loss: 0.0354 - val_acc: 0.9917
Epoch 5/12
60000/60000 [==============================] - 18s 297us/step - loss: 0.0704 - acc: 0.983
0 - val_loss: 0.0304 - val_acc: 0.9923
Epoch 6/12
60000/60000 [==============================] - 18s 296us/step - loss: 0.0639 - acc: 0.985
1 - val_loss: 0.0315 - val_acc: 0.9921
Epoch 7/12
60000/60000 [==============================] - 17s 290us/step - loss: 0.0568 - acc: 0.986
6 - val_loss: 0.0290 - val_acc: 0.9930
```

```
Epoch 8/12
60000/60000 [==============================] - 17s 291us/step - loss: 0.0481 - acc: 0.988
3 - val_loss: 0.0373 - val_acc: 0.9914
Epoch 9/12
60000/60000 [==============================] - 17s 292us/step - loss: 0.0488 - acc: 0.988
4 - val_loss: 0.0274 - val_acc: 0.9938
Epoch 10/12
60000/60000 [==============================] - 18s 296us/step - loss: 0.0449 - acc: 0.989
3 - val_loss: 0.0256 - val_acc: 0.9932
Epoch 11/12
60000/60000 [==============================] - 18s 292us/step - loss: 0.0419 - acc: 0.990
5 - val_loss: 0.0454 - val_acc: 0.9909
Epoch 12/12
60000/60000 [==============================] - 17s 291us/step - loss: 0.0388 - acc: 0.990
4 - val_loss: 0.0254 - val_acc: 0.9938
Test loss: 0.025403328641527334
Test accuracy: 0.9938
```

In [0]:

```
model9.summary()
```

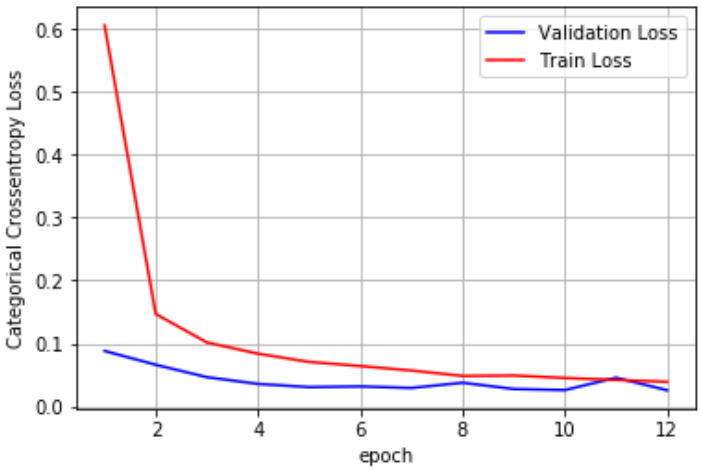
```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_40 (Conv2D)           (None, 28, 28, 256)       2560
_________________________________________________________________
batch_normalization_32 (Batc (None, 28, 28, 256)       1024
_________________________________________________________________
max_pooling2d_33 (MaxPooling (None, 14, 14, 256)       0
_________________________________________________________________
dropout_29 (Dropout)         (None, 14, 14, 256)       0
_________________________________________________________________
conv2d_41 (Conv2D)           (None, 14, 14, 128)       295040
_________________________________________________________________
batch_normalization_33 (Batc (None, 14, 14, 128)       512
_________________________________________________________________
max_pooling2d_34 (MaxPooling (None, 7, 7, 128)         0
_________________________________________________________________
dropout_30 (Dropout)         (None, 7, 7, 128)         0
_________________________________________________________________
conv2d_42 (Conv2D)           (None, 7, 7, 64)          73792
_________________________________________________________________
batch_normalization_34 (Batc (None, 7, 7, 64)          256
_________________________________________________________________
max_pooling2d_35 (MaxPooling (None, 3, 3, 64)          0
_________________________________________________________________
dropout_31 (Dropout)         (None, 3, 3, 64)          0
_________________________________________________________________
conv2d_43 (Conv2D)           (None, 3, 3, 64)          36928
_________________________________________________________________
batch_normalization_35 (Batc (None, 3, 3, 64)          256
_________________________________________________________________
max_pooling2d_36 (MaxPooling (None, 1, 1, 64)          0
_________________________________________________________________
dropout_32 (Dropout)         (None, 1, 1, 64)          0
_________________________________________________________________
conv2d_44 (Conv2D)           (None, 1, 1, 32)          18464
_________________________________________________________________
batch_normalization_36 (Batc (None, 1, 1, 32)          128
_________________________________________________________________
dropout_33 (Dropout)         (None, 1, 1, 32)          0
_________________________________________________________________
conv2d_45 (Conv2D)           (None, 1, 1, 32)          9248
_________________________________________________________________
batch_normalization_37 (Batc (None, 1, 1, 32)          128
_________________________________________________________________
dropout_34 (Dropout)         (None, 1, 1, 32)          0
_________________________________________________________________
conv2d_46 (Conv2D)           (None, 1, 1, 16)          4624
_________________________________________________________________
batch_normalization_38 (Batc (None, 1, 1, 16)          64
```

```
_________________________________________________________________
dropout_35 (Dropout)         (None, 1, 1, 16)          0
_________________________________________________________________
flatten_15 (Flatten)         (None, 16)                0
_________________________________________________________________
dense_30 (Dense)             (None, 32)                544
_________________________________________________________________
dense_31 (Dense)             (None, 10)                330
=================================================================
Total params: 443,898
Trainable params: 442,714
Non-trainable params: 1,184
_________________________________________________________________
```

In [0]:

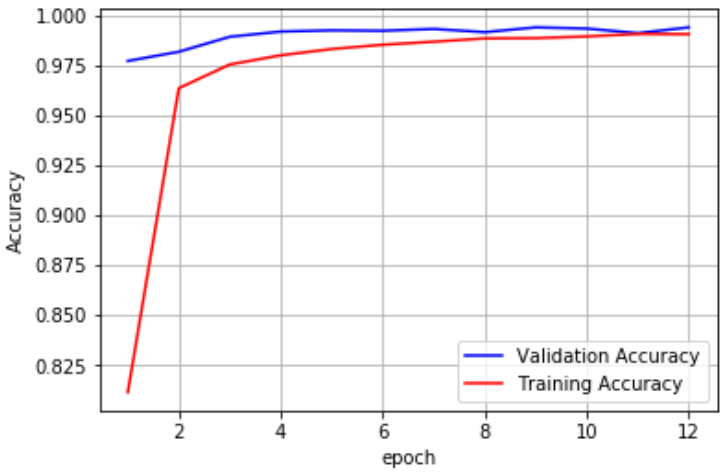
```
score = model9.evaluate(x_test, y_test, verbose=0)
print('Test score:', score[0])
print('Test accuracy:', score[1])
fig,ax = plt.subplots(1,1)
ax.set_xlabel('epoch') ; ax.set_ylabel('Categorical Crossentropy Loss')
x = list(range(1,epochs+1))
vl = inspect.history['val_loss']
tl = inspect.history['loss']
plt_dynamic(x, vl, tl, ax)
```

```
Test score: 0.025403328641527334
Test accuracy: 0.9938
```



In [0]:

```
fig,ax = plt.subplots(1,1)
ax.set_xlabel('epoch') ; ax.set_ylabel('Accuracy')
x = list(range(1,epochs+1))
vacc = inspect.history['val_acc']
tacc = inspect.history['acc']
plt_dynamic1(x, vacc, tacc, ax)
```



In [0]:

```
x= [model1.evaluate(x_test, y_test, verbose=0)[0],model2.evaluate(x_test, y_test, verbos
e=0)[0],model3.evaluate(x_test, y_test, verbose=0)[0],model4.evaluate(x_test, y_test, ve
rbose=0)[0],model5.evaluate(x_test, y_test, verbose=0)[0],model6.evaluate(x_test, y_test
, verbose=0)[0],model7.evaluate(x_test, y_test, verbose=0)[0],model8.evaluate(x_test, y_
test, verbose=0)[0],model9.evaluate(x_test, y_test, verbose=0)[0]]
```

In [0]:

```
y= [model1.evaluate(x_test, y_test, verbose=0)[1],model2.evaluate(x_test, y_test, verbos
e=0)[1],model3.evaluate(x_test, y_test, verbose=0)[1],model4.evaluate(x_test, y_test, ve
rbose=0)[1],model5.evaluate(x_test, y_test, verbose=0)[1],model6.evaluate(x_test, y_test
, verbose=0)[1],model7.evaluate(x_test, y_test, verbose=0)[1],model8.evaluate(x_test, y_
test, verbose=0)[1],model9.evaluate(x_test, y_test, verbose=0)[1]]
```

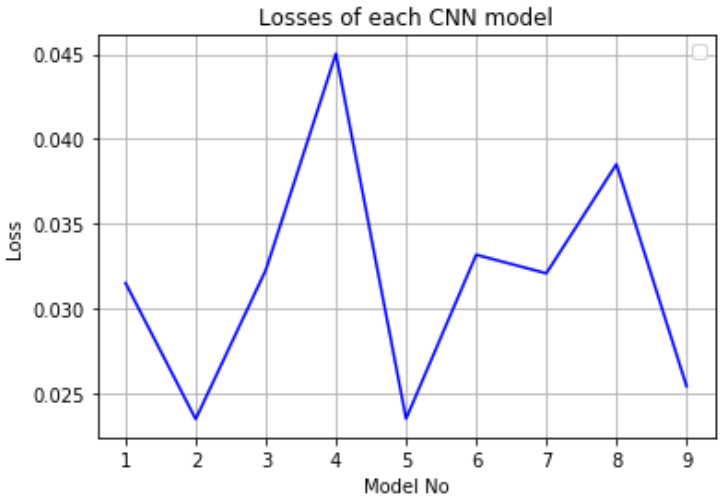
In [0]:

```
models = list(range(1,10))
```

In [0]:

```
fig,ax = plt.subplots(1,1)
ax.set_xlabel('Model No') ; ax.set_ylabel('Loss')
ax.plot(models, x, 'b')
plt.legend()
plt.grid()
plt.title('Losses of each CNN model')
#plt.show()
fig.canvas.draw()
```

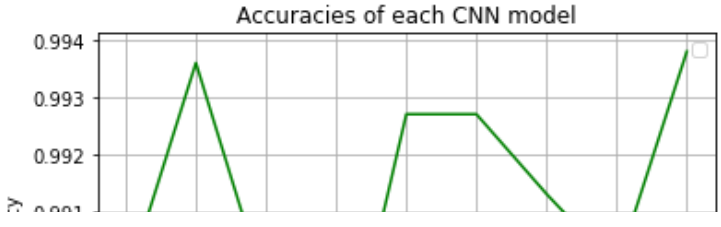
```
W0825 12:42:55.277995 140359865685888 legend.py:1289] No handles with labels found to put
in legend.
```

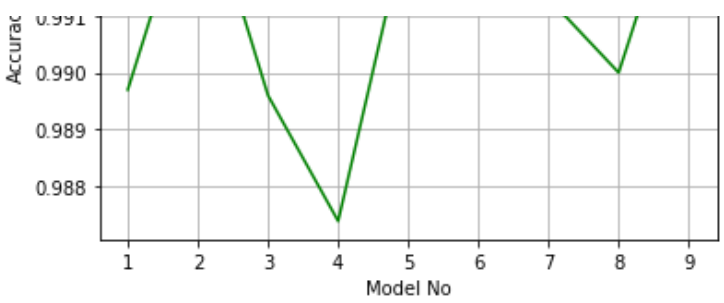


In [0]:

```
fig,ax = plt.subplots(1,1)
ax.set_xlabel('Model No') ; ax.set_ylabel('Accuracy')
ax.plot(models, y, 'g')
plt.legend()
plt.grid()
plt.title('Accuracies of each CNN model')
#plt.show()
fig.canvas.draw()
```

```
W0825 12:45:15.068250 140359865685888 legend.py:1289] No handles with labels found to put
in legend.
```





10. 3 CONVOLUTIONAL LAYERS (MAX POOLING , 2X2 FILTER-RANDOM UNIFORM INITIALISER)

In [5]:

```
#from keras.layers.normalization import BatchNormalization
model1 = Sequential()

model1.add(Conv2D(64, kernel_size=(2, 2),
                 activation='relu',
                 input_shape=input_shape,kernel_initializer='random_uniform'))
model1.add(MaxPooling2D(pool_size=(2, 2)))


model1.add(Conv2D(32, (2, 2), activation='relu',kernel_initializer='random_uniform'))
model1.add(MaxPooling2D(pool_size=(2, 2)))

model1.add(Conv2D(32, (2, 2), activation='relu',kernel_initializer='random_uniform'))
model1.add(MaxPooling2D(pool_size=(2, 2)))

model1.add(Flatten())
model1.add(Dense(128, activation='relu',kernel_initializer='random_uniform'))
model1.add(Dropout(0.5))
model1.add(Dense(num_classes, activation='softmax'))

model1.compile(loss=keras.losses.categorical_crossentropy,
               optimizer=keras.optimizers.Adadelta(),
               metrics=['accuracy'])

inspect = model1.fit(x_train, y_train,
          batch_size=batch_size,
          epochs=epochs,
          verbose=1,
          validation_data=(x_test, y_test))
score = model1.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 [==============================] - 6s 107us/step - loss: 0.8491 - acc: 0.7100
- val_loss: 0.1752 - val_acc: 0.9444
Epoch 2/12
60000/60000 [==============================] - 6s 97us/step - loss: 0.2067 - acc: 0.9372
- val_loss: 0.1065 - val_acc: 0.9668
Epoch 3/12
60000/60000 [==============================] - 6s 96us/step - loss: 0.1483 - acc: 0.9561
- val_loss: 0.0824 - val_acc: 0.9747
Epoch 4/12
60000/60000 [==============================] - 6s 95us/step - loss: 0.1204 - acc: 0.9638
- val_loss: 0.0804 - val_acc: 0.9750
Epoch 5/12
60000/60000 [==============================] - 6s 96us/step - loss: 0.1066 - acc: 0.9680
- val_loss: 0.0674 - val_acc: 0.9784
Epoch 6/12
60000/60000 [==============================] - 6s 95us/step - loss: 0.0935 - acc: 0.9722
- val_loss: 0.0688 - val_acc: 0.9791
Epoch 7/12
60000/60000 [==============================] - 6s 96us/step - loss: 0.0849 - acc: 0.9746
- val_loss: 0.0556 - val_acc: 0.9818
Epoch 8/12
60000/60000 [==============================] - 6s 95us/step - loss: 0.0783 - acc: 0.9761
```

```
- val_loss: 0.0541 - val_acc: 0.9844
Epoch 9/12
60000/60000 [==============================] - 6s 95us/step - loss: 0.0735 - acc: 0.9780
- val_loss: 0.0511 - val_acc: 0.9834
Epoch 10/12
60000/60000 [==============================] - 6s 96us/step - loss: 0.0669 - acc: 0.9798
- val_loss: 0.0495 - val_acc: 0.9852
Epoch 11/12
60000/60000 [==============================] - 6s 96us/step - loss: 0.0629 - acc: 0.9812
- val_loss: 0.0522 - val_acc: 0.9837
Epoch 12/12
60000/60000 [==============================] - 6s 96us/step - loss: 0.0587 - acc: 0.9816
- val_loss: 0.0449 - val_acc: 0.9862
Test loss: 0.04492342894774338
Test accuracy: 0.9862
```

In [6]:

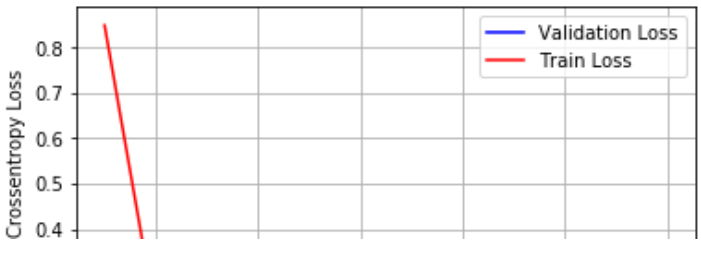
```
model1.summary()
```

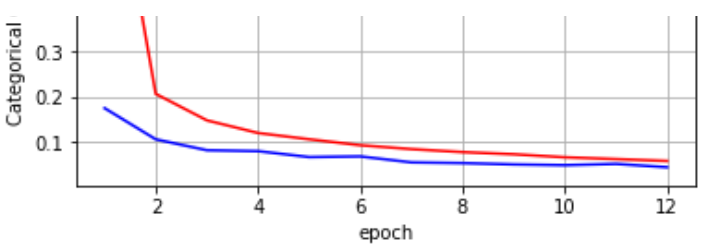
```
Model: "sequential_3"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_4 (Conv2D)            (None, 27, 27, 64)        320
_________________________________________________________________
max_pooling2d_2 (MaxPooling2 (None, 13, 13, 64)        0
_________________________________________________________________
conv2d_5 (Conv2D)            (None, 12, 12, 32)        8224
_________________________________________________________________
max_pooling2d_3 (MaxPooling2 (None, 6, 6, 32)          0
_________________________________________________________________
conv2d_6 (Conv2D)            (None, 5, 5, 32)          4128
_________________________________________________________________
max_pooling2d_4 (MaxPooling2 (None, 2, 2, 32)          0
_________________________________________________________________
flatten_2 (Flatten)          (None, 128)               0
_________________________________________________________________
dense_3 (Dense)              (None, 128)               16512
_________________________________________________________________
dropout_3 (Dropout)          (None, 128)               0
_________________________________________________________________
dense_4 (Dense)              (None, 10)                1290
=================================================================
Total params: 30,474
Trainable params: 30,474
Non-trainable params: 0
_________________________________________________________________
```

In [7]:

```
score = model1.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')
x = list(range(1,epochs+1))
vl = inspect.history['val_loss']
tl = inspect.history['loss']
plt_dynamic(x, vl, tl, ax)
```

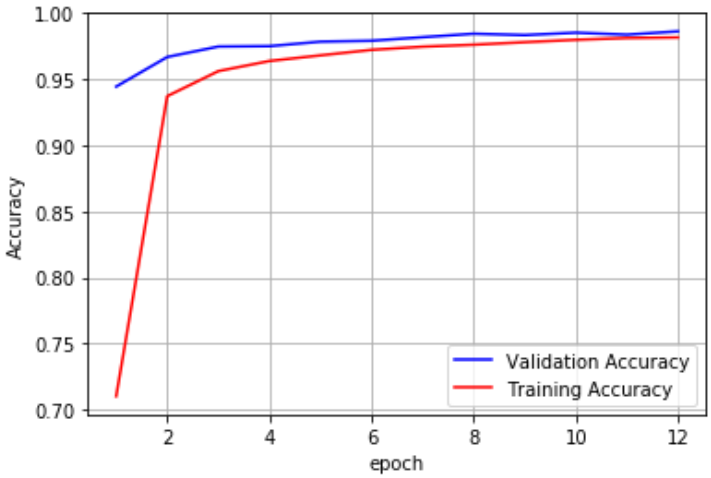
```
Test score: 0.04492342894774338
Test accuracy: 0.9862
```





In [8]:

```
fig,ax = plt.subplots(1,1)
ax.set_xlabel('epoch') ; ax.set_ylabel('Accuracy')
x = list(range(1,epochs+1))
vacc = inspect.history['val_acc']
tacc = inspect.history['acc']
plt_dynamic1(x, vacc, tacc, ax)
```



11. 3 CONVOLUTIONAL LAYERS (MAX POOLING , 2X2 FILTER-RANDOM UNIFORM INITIALISER ,TANH ACTIVATION)

In [9]:

```
#from keras.layers.normalization import BatchNormalization
model2 = Sequential()

model2.add(Conv2D(64, kernel_size=(2, 2),
                 activation='tanh',
                 input_shape=input_shape,kernel_initializer='random_uniform'))
model2.add(MaxPooling2D(pool_size=(2, 2)))


model2.add(Conv2D(32, (2, 2), activation='tanh',kernel_initializer='random_uniform'))
model2.add(MaxPooling2D(pool_size=(2, 2)))

model2.add(Conv2D(32, (2, 2), activation='tanh',kernel_initializer='random_uniform'))
model2.add(MaxPooling2D(pool_size=(2, 2)))

model2.add(Flatten())
model2.add(Dense(128, activation='tanh',kernel_initializer='random_uniform'))
model2.add(Dropout(0.5))
model2.add(Dense(num_classes, activation='softmax'))

model2.compile(loss=keras.losses.categorical_crossentropy,
               optimizer=keras.optimizers.Adadelta(),
               metrics=['accuracy'])

inspect = model2.fit(x_train, y_train,
          batch_size=batch_size,
          epochs=epochs,
          verbose=1,
          validation_data=(x_test, y_test))
score = model2.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 114us/step - loss: 0.5136 - acc: 0.8313
- val_loss: 0.1369 - val_acc: 0.9578
Epoch 2/12
60000/60000 [==============================] - 6s 103us/step - loss: 0.1358 - acc: 0.9581
- val_loss: 0.0916 - val_acc: 0.9703
Epoch 3/12
60000/60000 [==============================] - 6s 100us/step - loss: 0.1038 - acc: 0.9681
- val_loss: 0.0743 - val_acc: 0.9770
Epoch 4/12
60000/60000 [==============================] - 6s 101us/step - loss: 0.0898 - acc: 0.9726
- val_loss: 0.0703 - val_acc: 0.9775
Epoch 5/12
60000/60000 [==============================] - 6s 102us/step - loss: 0.0776 - acc: 0.9767
- val_loss: 0.0660 - val_acc: 0.9795
Epoch 6/12
60000/60000 [==============================] - 6s 100us/step - loss: 0.0711 - acc: 0.9778
- val_loss: 0.0576 - val_acc: 0.9817
Epoch 7/12
60000/60000 [==============================] - 6s 98us/step - loss: 0.0649 - acc: 0.9801
- val_loss: 0.0612 - val_acc: 0.9808
Epoch 8/12
60000/60000 [==============================] - 6s 98us/step - loss: 0.0607 - acc: 0.9815
- val_loss: 0.0603 - val_acc: 0.9822
Epoch 9/12
60000/60000 [==============================] - 6s 97us/step - loss: 0.0574 - acc: 0.9822
- val_loss: 0.0570 - val_acc: 0.9827
Epoch 10/12
60000/60000 [==============================] - 6s 97us/step - loss: 0.0525 - acc: 0.9838
- val_loss: 0.0539 - val_acc: 0.9819
Epoch 11/12
60000/60000 [==============================] - 6s 96us/step - loss: 0.0494 - acc: 0.9846
- val_loss: 0.0552 - val_acc: 0.9839
Epoch 12/12
60000/60000 [==============================] - 6s 96us/step - loss: 0.0477 - acc: 0.9851
- val_loss: 0.0632 - val_acc: 0.9825
Test loss: 0.0631999080858659
Test accuracy: 0.9825
```

In [10]:

```
model2.summary()
```

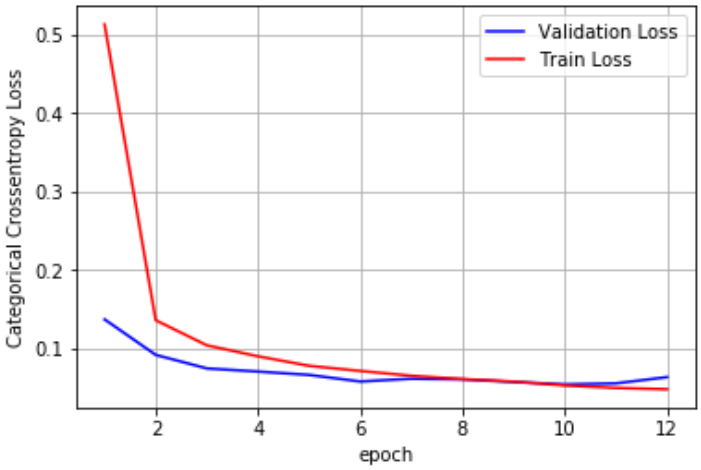
```
Model: "sequential_4"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_7 (Conv2D)            (None, 27, 27, 64)        320
_________________________________________________________________
max_pooling2d_5 (MaxPooling2 (None, 13, 13, 64)        0
_________________________________________________________________
conv2d_8 (Conv2D)            (None, 12, 12, 32)        8224
_________________________________________________________________
max_pooling2d_6 (MaxPooling2 (None, 6, 6, 32)          0
_________________________________________________________________
conv2d_9 (Conv2D)            (None, 5, 5, 32)          4128
_________________________________________________________________
max_pooling2d_7 (MaxPooling2 (None, 2, 2, 32)          0
_________________________________________________________________
flatten_3 (Flatten)          (None, 128)               0
_________________________________________________________________
dense_5 (Dense)              (None, 128)               16512
_________________________________________________________________
dropout_4 (Dropout)          (None, 128)               0
_________________________________________________________________
dense_6 (Dense)              (None, 10)                1290
=================================================================
Total params: 30,474
Trainable params: 30,474
```

```
Non-trainable params: 0
_________________________________________________________________
```

In [11]:

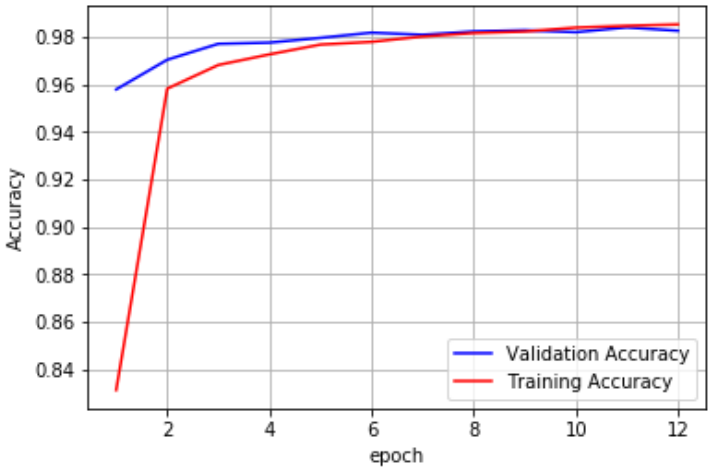
```
score = model2.evaluate(x_test, y_test, verbose=0)
print('Test score:', score[0])
print('Test accuracy:', score[1])
fig,ax = plt.subplots(1,1)
ax.set_xlabel('epoch') ; ax.set_ylabel('Categorical Crossentropy Loss')
x = list(range(1,epochs+1))
vl = inspect.history['val_loss']
tl = inspect.history['loss']
plt_dynamic(x, vl, tl, ax)
```

```
Test score: 0.0631999080858659
Test accuracy: 0.9825
```



In [12]:

```
fig,ax = plt.subplots(1,1)
ax.set_xlabel('epoch') ; ax.set_ylabel('Accuracy')
x = list(range(1,epochs+1))
vacc = inspect.history['val_acc']
tacc = inspect.history['acc']
plt_dynamic1(x, vacc, tacc, ax)
```



12. 3 CONVOLUTIONAL LAYERS (MAX POOLING ,BATCH NORM,DROPOUT=(0.4) 2X2 FILTER-ORTHOGONAL INITIALISER ,TANH ACTIVATION)

In [18]:

```
from keras.layers.normalization import BatchNormalization
model3 = Sequential()

model3.add(Conv2D(64, kernel_size=(2, 2),
                 activation='tanh',
```

```
                 input_shape=input_shape,kernel_initializer='orthogonal'))
model3.add(BatchNormalization())
model3.add(MaxPooling2D(pool_size=(2, 2)))
model3.add(Dropout(0.4))


model3.add(Conv2D(32, (2, 2), activation='tanh',kernel_initializer='orthogonal'))
model3.add(BatchNormalization())
model3.add(MaxPooling2D(pool_size=(2, 2)))
model3.add(Dropout(0.4))

model3.add(Conv2D(32, (2, 2), activation='tanh',kernel_initializer='orthogonal'))
model3.add(BatchNormalization())
model3.add(MaxPooling2D(pool_size=(2, 2)))
model3.add(Dropout(0.4))

model3.add(Flatten())
model3.add(Dense(128, activation='tanh'))
model3.add(Dropout(0.4))
model3.add(Dense(num_classes, activation='softmax'))

model3.compile(loss=keras.losses.categorical_crossentropy,
              optimizer=keras.optimizers.Adadelta(),
              metrics=['accuracy'])

inspect = model3.fit(x_train, y_train,
          batch_size=batch_size,
          epochs=epochs,
          verbose=1,
          validation_data=(x_test, y_test))
score = model3.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 170us/step - loss: 1.2124 - acc: 0.590
6 - val_loss: 0.4706 - val_acc: 0.8536
Epoch 2/12
60000/60000 [==============================] - 9s 150us/step - loss: 0.5745 - acc: 0.8124
- val_loss: 0.5390 - val_acc: 0.8286
Epoch 3/12
60000/60000 [==============================] - 9s 150us/step - loss: 0.4348 - acc: 0.8603
- val_loss: 0.2854 - val_acc: 0.9100
Epoch 4/12
60000/60000 [==============================] - 9s 150us/step - loss: 0.3666 - acc: 0.8842
- val_loss: 0.1562 - val_acc: 0.9510
Epoch 5/12
60000/60000 [==============================] - 9s 152us/step - loss: 0.3253 - acc: 0.8980
- val_loss: 0.1373 - val_acc: 0.9574
Epoch 6/12
60000/60000 [==============================] - 9s 152us/step - loss: 0.2971 - acc: 0.9069
- val_loss: 0.1358 - val_acc: 0.9565
Epoch 7/12
60000/60000 [==============================] - 9s 151us/step - loss: 0.2755 - acc: 0.9142
- val_loss: 0.1017 - val_acc: 0.9687
Epoch 8/12
60000/60000 [==============================] - 9s 156us/step - loss: 0.2551 - acc: 0.9197
- val_loss: 0.0934 - val_acc: 0.9711
Epoch 9/12
60000/60000 [==============================] - 9s 152us/step - loss: 0.2426 - acc: 0.9250
- val_loss: 0.0943 - val_acc: 0.9725
Epoch 10/12
60000/60000 [==============================] - 9s 154us/step - loss: 0.2354 - acc: 0.9267
- val_loss: 0.0936 - val_acc: 0.9703
Epoch 11/12
60000/60000 [==============================] - 9s 152us/step - loss: 0.2192 - acc: 0.9301
- val_loss: 0.0925 - val_acc: 0.9719
Epoch 12/12
60000/60000 [==============================] - 9s 152us/step - loss: 0.2121 - acc: 0.9334
- val_loss: 0.0757 - val_acc: 0.9772
Test loss: 0.07570360766109079
```

```
Test accuracy: 0.9772
```

In [15]:

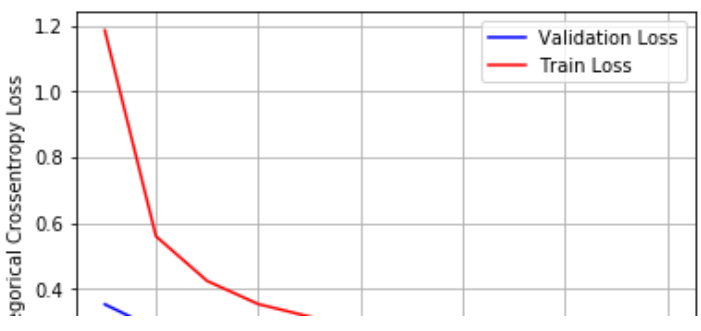
```
model3.summary()
```

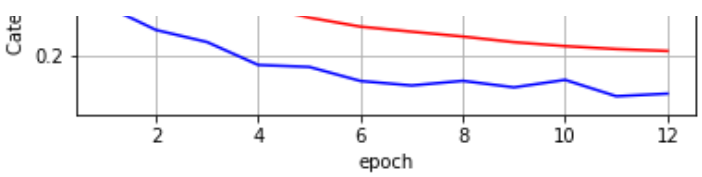
```
Model: "sequential_6"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_11 (Conv2D)           (None, 27, 27, 64)        320
_________________________________________________________________
batch_normalization_1 (Batch (None, 27, 27, 64)        256
_________________________________________________________________
max_pooling2d_8 (MaxPooling2 (None, 13, 13, 64)        0
_________________________________________________________________
dropout_5 (Dropout)          (None, 13, 13, 64)        0
_________________________________________________________________
conv2d_12 (Conv2D)           (None, 12, 12, 32)        8224
_________________________________________________________________
batch_normalization_2 (Batch (None, 12, 12, 32)        128
_________________________________________________________________
max_pooling2d_9 (MaxPooling2 (None, 6, 6, 32)          0
_________________________________________________________________
dropout_6 (Dropout)          (None, 6, 6, 32)          0
_________________________________________________________________
conv2d_13 (Conv2D)           (None, 5, 5, 32)          4128
_________________________________________________________________
batch_normalization_3 (Batch (None, 5, 5, 32)          128
_________________________________________________________________
max_pooling2d_10 (MaxPooling (None, 2, 2, 32)          0
_________________________________________________________________
dropout_7 (Dropout)          (None, 2, 2, 32)          0
_________________________________________________________________
flatten_4 (Flatten)          (None, 128)               0
_________________________________________________________________
dense_7 (Dense)              (None, 128)               16512
_________________________________________________________________
dropout_8 (Dropout)          (None, 128)               0
_________________________________________________________________
dense_8 (Dense)              (None, 10)                1290
=================================================================
Total params: 30,986
Trainable params: 30,730
Non-trainable params: 256
_________________________________________________________________
```

In [16]:

```
score = model3.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')
x = list(range(1,epochs+1))
vl = inspect.history['val_loss']
tl = inspect.history['loss']
plt_dynamic(x, vl, tl, ax)
```

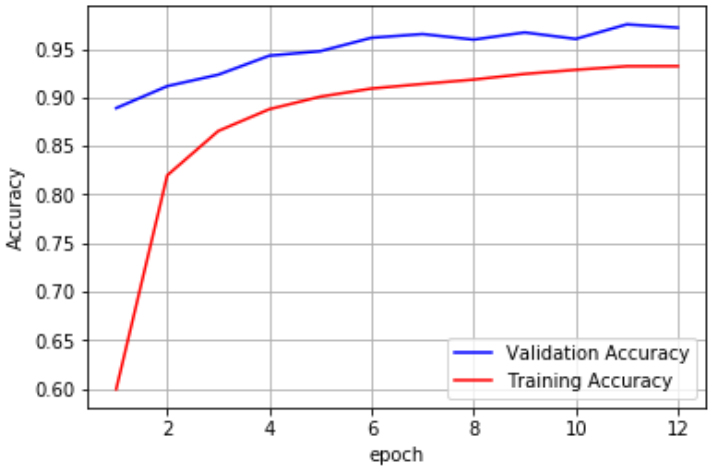
```
Test score: 0.0859176158150658
Test accuracy: 0.9718
```





In [17]:

```
fig,ax = plt.subplots(1,1)
ax.set_xlabel('epoch') ; ax.set_ylabel('Accuracy')
x = list(range(1,epochs+1))
vacc = inspect.history['val_acc']
tacc = inspect.history['acc']
plt_dynamic1(x, vacc, tacc, ax)
```



13. 3 CONVOLUTIONAL LAYERS (MAX POOLING, 3X3 FILTER-ORTHOGONAL INITIALISER ,SIGMOID ACTIVATION)

In [20]:

```
from keras.layers.normalization import BatchNormalization
model4 = Sequential()

model4.add(Conv2D(64, kernel_size=(3,3),
                 activation='sigmoid',
                 input_shape=input_shape,kernel_initializer='orthogonal'))
model4.add(MaxPooling2D(pool_size=(2, 2)))



model4.add(Conv2D(32, (3, 3), activation='sigmoid',kernel_initializer='orthogonal'))
model4.add(MaxPooling2D(pool_size=(2, 2)))


model4.add(Conv2D(32, (3, 3), activation='sigmoid',kernel_initializer='orthogonal'))
model4.add(MaxPooling2D(pool_size=(2, 2)))

model4.add(Flatten())
model4.add(Dense(128, activation='sigmoid'))
model4.add(Dropout(0.4))
model4.add(Dense(num_classes, activation='softmax'))

model4.compile(loss=keras.losses.categorical_crossentropy,
              optimizer=keras.optimizers.Adadelta(),
              metrics=['accuracy'])

inspect = model4.fit(x_train, y_train,
          batch_size=batch_size,
          epochs=epochs,
          verbose=1,
          validation_data=(x_test, y_test))
score = model4.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 126us/step - loss: 2.3453 - acc: 0.1022
- val_loss: 2.3022 - val_acc: 0.1135
Epoch 2/12
60000/60000 [==============================] - 6s 103us/step - loss: 2.3064 - acc: 0.1058
- val_loss: 2.3022 - val_acc: 0.1009
Epoch 3/12
60000/60000 [==============================] - 6s 101us/step - loss: 2.3038 - acc: 0.1077
- val_loss: 2.3013 - val_acc: 0.1135
Epoch 4/12
60000/60000 [==============================] - 6s 99us/step - loss: 2.3024 - acc: 0.1097
- val_loss: 2.3012 - val_acc: 0.1135
Epoch 5/12
60000/60000 [==============================] - 6s 99us/step - loss: 2.3021 - acc: 0.1108
- val_loss: 2.3013 - val_acc: 0.1135
Epoch 6/12
60000/60000 [==============================] - 6s 102us/step - loss: 2.3021 - acc: 0.1113
- val_loss: 2.3011 - val_acc: 0.1135
Epoch 7/12
60000/60000 [==============================] - 6s 104us/step - loss: 2.3016 - acc: 0.1118
- val_loss: 2.3015 - val_acc: 0.1135
Epoch 8/12
60000/60000 [==============================] - 6s 101us/step - loss: 2.3018 - acc: 0.1113
- val_loss: 2.3011 - val_acc: 0.1135
Epoch 9/12
60000/60000 [==============================] - 6s 104us/step - loss: 2.3016 - acc: 0.1121
- val_loss: 2.3014 - val_acc: 0.1135
Epoch 10/12
60000/60000 [==============================] - 6s 100us/step - loss: 2.3015 - acc: 0.1121
- val_loss: 2.3014 - val_acc: 0.1135
Epoch 11/12
60000/60000 [==============================] - 6s 100us/step - loss: 2.3017 - acc: 0.1125
- val_loss: 2.3010 - val_acc: 0.1135
Epoch 12/12
60000/60000 [==============================] - 6s 100us/step - loss: 2.3017 - acc: 0.1125
- val_loss: 2.3010 - val_acc: 0.1135
Test loss: 2.3009641578674316
Test accuracy: 0.1135
```

In [21]:

```
model4.summary()
```

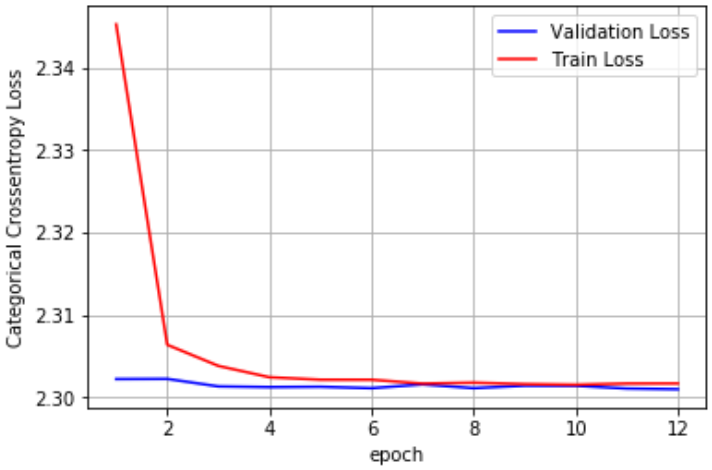
```
Model: "sequential_9"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_20 (Conv2D)           (None, 26, 26, 64)        640
_________________________________________________________________
max_pooling2d_17 (MaxPooling (None, 13, 13, 64)        0
_________________________________________________________________
conv2d_21 (Conv2D)           (None, 11, 11, 32)        18464
_________________________________________________________________
max_pooling2d_18 (MaxPooling (None, 5, 5, 32)          0
_________________________________________________________________
conv2d_22 (Conv2D)           (None, 3, 3, 32)          9248
_________________________________________________________________
max_pooling2d_19 (MaxPooling (None, 1, 1, 32)          0
_________________________________________________________________
flatten_7 (Flatten)          (None, 32)                0
_________________________________________________________________
dense_13 (Dense)             (None, 128)               4224
_________________________________________________________________
dropout_14 (Dropout)         (None, 128)               0
_________________________________________________________________
dense_14 (Dense)             (None, 10)                1290
=================================================================
Total params: 33,866
Trainable params: 33,866
```

```
Non-trainable params: 0
_________________________________________________________________
```

In [22]:

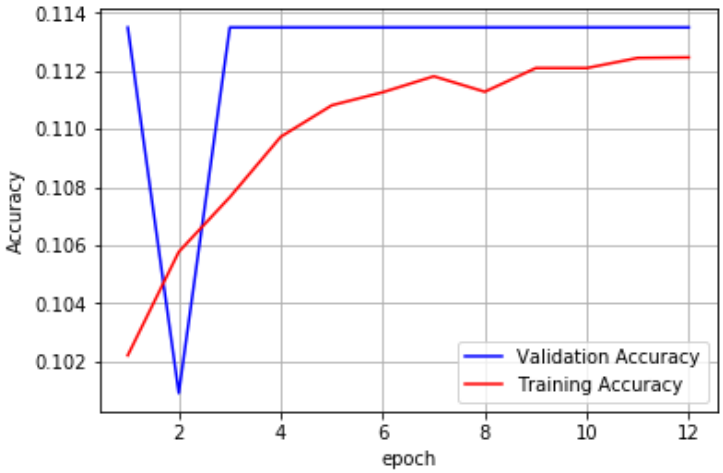
```
score = model4.evaluate(x_test, y_test, verbose=0)
print('Test score:', score[0])
print('Test accuracy:', score[1])
fig,ax = plt.subplots(1,1)
ax.set_xlabel('epoch') ; ax.set_ylabel('Categorical Crossentropy Loss')
x = list(range(1,epochs+1))
vl = inspect.history['val_loss']
tl = inspect.history['loss']
plt_dynamic(x, vl, tl, ax)
```

```
Test score: 2.3009641578674316
Test accuracy: 0.1135
```



In [23]:

```
fig,ax = plt.subplots(1,1)
ax.set_xlabel('epoch') ; ax.set_ylabel('Accuracy')
x = list(range(1,epochs+1))
vacc = inspect.history['val_acc']
tacc = inspect.history['acc']
plt_dynamic1(x, vacc, tacc, ax)
```



14. 5 CONVOLUTIONAL LAYERS (MAX POOLING AND BATCH NORMALIZATION 3X3 FILTER,ELU ACTIVATION,RMSProp OPTIMISER)

In [27]:

```
from keras.layers.normalization import BatchNormalization
model5 = Sequential()
#1ST
model5.add(Conv2D(256, kernel_size=(3, 3),
                 activation='elu',
```

```
                 input_shape=input_shape,padding="same",kernel_initializer='zeros'))
model5.add(BatchNormalization())
model5.add(MaxPooling2D(pool_size=(2, 2)))
#model5.add(Dropout(0.6))


#2ND
model5.add(Conv2D(128, (3, 3), activation='elu',padding="same",kernel_initializer='zeros
'))
model5.add(BatchNormalization())
model5.add(MaxPooling2D(pool_size=(2, 2)))
#model5.add(Dropout(0.5))


#3RD
model5.add(Conv2D(64, (3, 3), activation='elu',padding="same",kernel_initializer='zeros'
))
model5.add(BatchNormalization())
model5.add(MaxPooling2D(pool_size=(2, 2)))
#model5.add(Dropout(0.5))

#4TH
model5.add(Conv2D(32, (3, 3), activation='elu',padding="same",kernel_initializer='zeros'
))
model5.add(BatchNormalization())
model5.add(MaxPooling2D(pool_size=(2, 2)))
#model5.add(Dropout(0.5))

#5TH
model5.add(Conv2D(16, (3, 3), activation='elu',padding="same",kernel_initializer='zeros'
))
model5.add(BatchNormalization())
#model.add(MaxPooling2D(pool_size=(2, 2)))
#model5.add(Dropout(0.5))

model5.add(Flatten())
model5.add(Dense(32, activation='elu'))

model5.add(Dense(num_classes, activation='softmax'))

model5.compile(loss=keras.losses.categorical_crossentropy,
              optimizer=keras.optimizers.RMSprop(),
              metrics=['accuracy'])

inspect = model5.fit(x_train, y_train,
          batch_size=batch_size,
          epochs=epochs,
          verbose=1,
          validation_data=(x_test, y_test))
score = model5.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 [==============================] - 30s 505us/step - loss: 2.3017 - acc: 0.112
0 - val_loss: 2.3062 - val_acc: 0.1135
Epoch 2/12
60000/60000 [==============================] - 28s 468us/step - loss: 2.3015 - acc: 0.112
4 - val_loss: 2.3040 - val_acc: 0.1135
Epoch 3/12
60000/60000 [==============================] - 28s 471us/step - loss: 2.3015 - acc: 0.112
4 - val_loss: 2.3042 - val_acc: 0.1135
Epoch 4/12
60000/60000 [==============================] - 28s 470us/step - loss: 2.3015 - acc: 0.112
4 - val_loss: 2.3038 - val_acc: 0.1032
Epoch 5/12
60000/60000 [==============================] - 28s 473us/step - loss: 2.3015 - acc: 0.112
4 - val_loss: 2.3033 - val_acc: 0.1135
Epoch 6/12
60000/60000 [==============================] - 28s 470us/step - loss: 2.3014 - acc: 0.112
3 - val_loss: 2.3017 - val_acc: 0.1135
```

```
Epoch 7/12
60000/60000 [==============================] - 28s 468us/step - loss: 2.3014 - acc: 0.112
0 - val_loss: 2.3025 - val_acc: 0.1135
Epoch 8/12
60000/60000 [==============================] - 28s 474us/step - loss: 2.3015 - acc: 0.112
4 - val_loss: 2.3012 - val_acc: 0.1135
Epoch 9/12
60000/60000 [==============================] - 28s 468us/step - loss: 2.3015 - acc: 0.112
4 - val_loss: 2.3012 - val_acc: 0.1135
Epoch 10/12
60000/60000 [==============================] - 28s 474us/step - loss: 2.3014 - acc: 0.112
4 - val_loss: 2.3015 - val_acc: 0.1135
Epoch 11/12
60000/60000 [==============================] - 28s 474us/step - loss: 2.3014 - acc: 0.112
4 - val_loss: 2.3011 - val_acc: 0.1135
Epoch 12/12
60000/60000 [==============================] - 28s 473us/step - loss: 2.3014 - acc: 0.112
4 - val_loss: 2.3017 - val_acc: 0.1135
Test loss: 2.3016848217010497
Test accuracy: 0.1135
```

In [28]:

```
model5.summary()
```

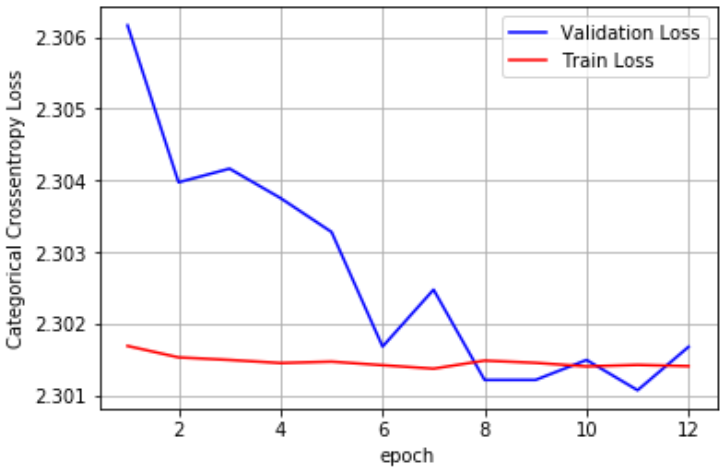
```
Model: "sequential_13"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_33 (Conv2D)           (None, 28, 28, 256)       2560
_________________________________________________________________
batch_normalization_15 (Batc (None, 28, 28, 256)       1024
_________________________________________________________________
max_pooling2d_27 (MaxPooling (None, 14, 14, 256)       0
_________________________________________________________________
conv2d_34 (Conv2D)           (None, 14, 14, 128)       295040
_________________________________________________________________
batch_normalization_16 (Batc (None, 14, 14, 128)       512
_________________________________________________________________
max_pooling2d_28 (MaxPooling (None, 7, 7, 128)         0
_________________________________________________________________
conv2d_35 (Conv2D)           (None, 7, 7, 64)          73792
_________________________________________________________________
batch_normalization_17 (Batc (None, 7, 7, 64)          256
_________________________________________________________________
max_pooling2d_29 (MaxPooling (None, 3, 3, 64)          0
_________________________________________________________________
conv2d_36 (Conv2D)           (None, 3, 3, 32)          18464
_________________________________________________________________
batch_normalization_18 (Batc (None, 3, 3, 32)          128
_________________________________________________________________
max_pooling2d_30 (MaxPooling (None, 1, 1, 32)          0
_________________________________________________________________
conv2d_37 (Conv2D)           (None, 1, 1, 16)          4624
_________________________________________________________________
batch_normalization_19 (Batc (None, 1, 1, 16)          64
_________________________________________________________________
flatten_9 (Flatten)          (None, 16)                0
_________________________________________________________________
dense_17 (Dense)             (None, 32)                544
_________________________________________________________________
dense_18 (Dense)             (None, 10)                330
=================================================================
Total params: 397,338
Trainable params: 396,346
Non-trainable params: 992
_________________________________________________________________
```

In [29]:

```
score = model5.evaluate(x_test, y_test, verbose=0)
print('Test score:', score[0])
```

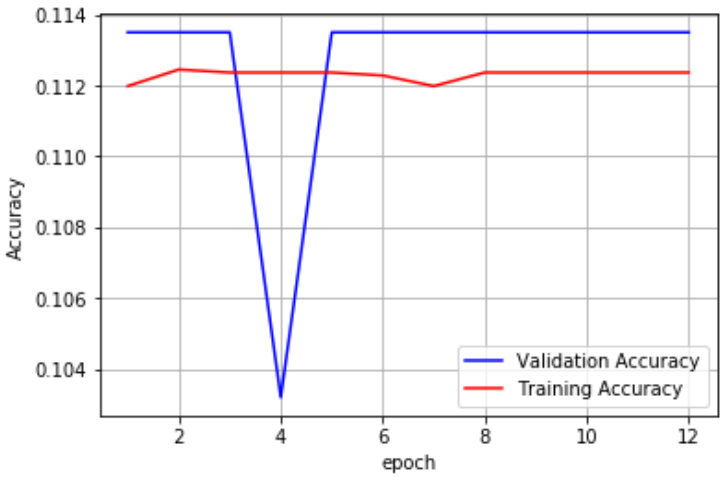
```
print('Test accuracy:', score[1])
fig,ax = plt.subplots(1,1)
ax.set_xlabel('epoch') ; ax.set_ylabel('Categorical Crossentropy Loss')
x = list(range(1,epochs+1))
vl = inspect.history['val_loss']
tl = inspect.history['loss']
plt_dynamic(x, vl, tl, ax)
```

```
Test score: 2.3016848217010497
Test accuracy: 0.1135
```



In [30]:

```
fig,ax = plt.subplots(1,1)
ax.set_xlabel('epoch') ; ax.set_ylabel('Accuracy')
x = list(range(1,epochs+1))
vacc = inspect.history['val_acc']
tacc = inspect.history['acc']
plt_dynamic1(x, vacc, tacc, ax)
```



15. 5 CONVOLUTIONAL LAYERS (MAX POOLING,DROPOUT AND BATCH NORMALIZATION 3X3 FILTER,RMSProp OPTIMISER, TANH Activation)

In [32]:

```
from keras.layers.normalization import BatchNormalization
model6 = Sequential()
#1ST
model6.add(Conv2D(256, kernel_size=(3, 3),
                 activation='tanh',
                 input_shape=input_shape,padding="same",kernel_initializer='ones'))
model6.add(BatchNormalization())
model6.add(MaxPooling2D(pool_size=(2, 2)))
#model15.add(Dropout(0.6))


#2ND
```

```
model6.add(Conv2D(128, (3, 3), activation='tanh',padding="same",kernel_initializer='ones
'))
model6.add(BatchNormalization())
model6.add(MaxPooling2D(pool_size=(2, 2)))
#model5.add(Dropout(0.5))


#3RD
model6.add(Conv2D(64, (3, 3), activation='tanh',padding="same",kernel_initializer='ones'
))
model6.add(BatchNormalization())
model6.add(MaxPooling2D(pool_size=(2, 2)))
#model5.add(Dropout(0.5))

#4TH
model6.add(Conv2D(32, (3, 3), activation='tanh',padding="same",kernel_initializer='ones'
))
model6.add(BatchNormalization())
model6.add(MaxPooling2D(pool_size=(2, 2)))
#model5.add(Dropout(0.5))

#5TH
model6.add(Conv2D(16, (3, 3), activation='tanh',padding="same",kernel_initializer='ones'
))
model6.add(BatchNormalization())
#model.add(MaxPooling2D(pool_size=(2, 2)))
#model5.add(Dropout(0.5))

model6.add(Flatten())
model6.add(Dense(32, activation='tanh'))

model6.add(Dense(num_classes, activation='softmax'))

model6.compile(loss=keras.losses.categorical_crossentropy,
              optimizer=keras.optimizers.RMSprop(),
              metrics=['accuracy'])

inspect = model6.fit(x_train, y_train,
          batch_size=batch_size,
          epochs=epochs,
          verbose=1,
          validation_data=(x_test, y_test))
score = model6.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 [==============================] - 30s 505us/step - loss: 2.1452 - acc: 0.181
9 - val_loss: 2.1244 - val_acc: 0.1849
Epoch 2/12
60000/60000 [==============================] - 28s 464us/step - loss: 2.1422 - acc: 0.183
4 - val_loss: 2.1243 - val_acc: 0.1903
Epoch 3/12
60000/60000 [==============================] - 28s 462us/step - loss: 2.1416 - acc: 0.182
9 - val_loss: 2.1280 - val_acc: 0.1857
Epoch 4/12
60000/60000 [==============================] - 28s 462us/step - loss: 2.1412 - acc: 0.181
8 - val_loss: 2.1236 - val_acc: 0.1850
Epoch 5/12
60000/60000 [==============================] - 28s 464us/step - loss: 2.1404 - acc: 0.184
4 - val_loss: 2.1242 - val_acc: 0.1903
Epoch 6/12
60000/60000 [==============================] - 28s 464us/step - loss: 2.1405 - acc: 0.181
3 - val_loss: 2.1249 - val_acc: 0.1856
Epoch 7/12
60000/60000 [==============================] - 28s 466us/step - loss: 2.1403 - acc: 0.181
9 - val_loss: 2.1243 - val_acc: 0.1856
Epoch 8/12
60000/60000 [==============================] - 28s 466us/step - loss: 2.1406 - acc: 0.181
9 - val_loss: 2.1232 - val_acc: 0.1849
Epoch 9/12
```

```
60000/60000 [==============================] - 28s 468us/step - loss: 2.1405 - acc: 0.181
7 - val_loss: 2.1232 - val_acc: 0.1857
Epoch 10/12
60000/60000 [==============================] - 28s 463us/step - loss: 2.1405 - acc: 0.182
9 - val_loss: 2.1241 - val_acc: 0.1856
Epoch 11/12
60000/60000 [==============================] - 28s 460us/step - loss: 2.1406 - acc: 0.183
1 - val_loss: 2.1253 - val_acc: 0.1857
Epoch 12/12
60000/60000 [==============================] - 28s 464us/step - loss: 2.1411 - acc: 0.180
9 - val_loss: 2.1242 - val_acc: 0.1857
Test loss: 2.1241648181915282
Test accuracy: 0.1857
```

In [33]:

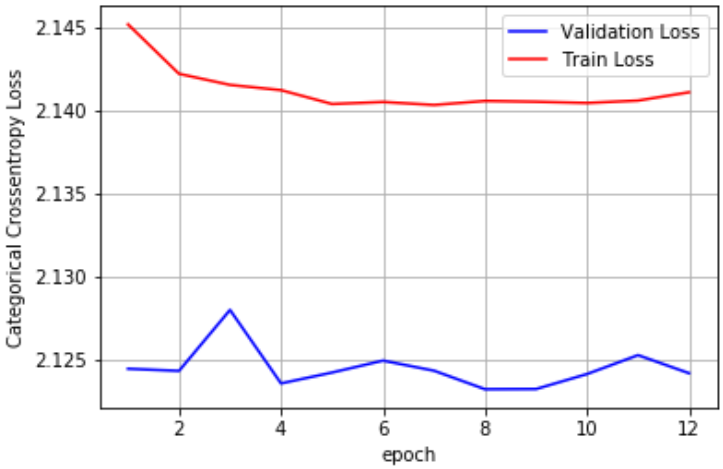
```
model6.summary()
```

```
Model: "sequential_15"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_42 (Conv2D)           (None, 28, 28, 256)       2560
_________________________________________________________________
batch_normalization_23 (Batc (None, 28, 28, 256)       1024
_________________________________________________________________
max_pooling2d_34 (MaxPooling (None, 14, 14, 256)       0
_________________________________________________________________
conv2d_43 (Conv2D)           (None, 14, 14, 128)       295040
_________________________________________________________________
batch_normalization_24 (Batc (None, 14, 14, 128)       512
_________________________________________________________________
max_pooling2d_35 (MaxPooling (None, 7, 7, 128)         0
_________________________________________________________________
conv2d_44 (Conv2D)           (None, 7, 7, 64)          73792
_________________________________________________________________
batch_normalization_25 (Batc (None, 7, 7, 64)          256
_________________________________________________________________
max_pooling2d_36 (MaxPooling (None, 3, 3, 64)          0
_________________________________________________________________
conv2d_45 (Conv2D)           (None, 3, 3, 32)          18464
_________________________________________________________________
batch_normalization_26 (Batc (None, 3, 3, 32)          128
_________________________________________________________________
max_pooling2d_37 (MaxPooling (None, 1, 1, 32)          0
_________________________________________________________________
conv2d_46 (Conv2D)           (None, 1, 1, 16)          4624
_________________________________________________________________
batch_normalization_27 (Batc (None, 1, 1, 16)          64
_________________________________________________________________
flatten_10 (Flatten)         (None, 16)                0
_________________________________________________________________
dense_19 (Dense)             (None, 32)                544
_________________________________________________________________
dense_20 (Dense)             (None, 10)                330
=================================================================
Total params: 397,338
Trainable params: 396,346
Non-trainable params: 992
_________________________________________________________________
```

In [34]:

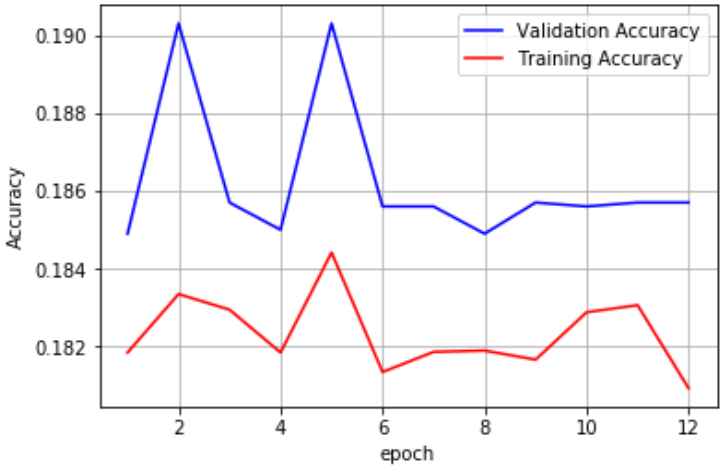
```
score = model6.evaluate(x_test, y_test, verbose=0)
print('Test score:', score[0])
print('Test accuracy:', score[1])
fig,ax = plt.subplots(1,1)
ax.set_xlabel('epoch') ; ax.set_ylabel('Categorical Crossentropy Loss')
x = list(range(1,epochs+1))
vl = inspect.history['val_loss']
tl = inspect.history['loss']
plt_dynamic(x, vl, tl, ax)
```

```
Test score: 2.1241648181915282
Test accuracy: 0.1857
```



In [35]:

```
fig,ax = plt.subplots(1,1)
ax.set_xlabel('epoch') ; ax.set_ylabel('Accuracy')
x = list(range(1,epochs+1))
vacc = inspect.history['val_acc']
tacc = inspect.history['acc']
plt_dynamic1(x, vacc, tacc, ax)
```



16. 5 CONVOLUTIONAL LAYERS (MAX POOLING, 3X3 FILTER,RMSProp OPTIMISER,TANH Activation,RANDOM UNIFORM INITIALISER)

In [37]:

```
from keras.layers.normalization import BatchNormalization
model7 = Sequential()
#1ST
model7.add(Conv2D(256, kernel_size=(3, 3),
                 activation='tanh',
                 input_shape=input_shape,padding="same",kernel_initializer='random_unifo
rm'))
#model7.add(BatchNormalization())
model7.add(MaxPooling2D(pool_size=(2, 2)))
#model5.add(Dropout(0.6))


#2ND
model7.add(Conv2D(128, (3, 3), activation='tanh',padding="same",kernel_initializer='rand
om_uniform'))

#model6.add(BatchNormalization())
model7.add(MaxPooling2D(pool_size=(2, 2)))
#model5.add(Dropout(0.5))
```

```
#3RD
model7.add(Conv2D(64, (3, 3), activation='tanh',padding="same",kernel_initializer='rando
m_uniform'))
#model7.add(BatchNormalization())
model7.add(MaxPooling2D(pool_size=(2, 2)))
#model5.add(Dropout(0.5))

#4TH
model7.add(Conv2D(32, (3, 3), activation='tanh',padding="same",kernel_initializer='rando
m_uniform'))
#model7.add(BatchNormalization())
#model7.add(MaxPooling2D(pool_size=(2, 2)))
#model5.add(Dropout(0.5))

#5TH
model7.add(Conv2D(16, (3, 3), activation='tanh',padding="same",kernel_initializer='rando
m_uniform'))
#model6.add(BatchNormalization())
#model7.add(MaxPooling2D(pool_size=(2, 2)))
#model5.add(Dropout(0.5))

model7.add(Flatten())
model7.add(Dense(32, activation='tanh'))

model7.add(Dense(num_classes, activation='softmax'))

model7.compile(loss=keras.losses.categorical_crossentropy,
              optimizer=keras.optimizers.RMSprop(),
              metrics=['accuracy'])

inspect = model7.fit(x_train, y_train,
          batch_size=batch_size,
          epochs=epochs,
          verbose=1,
          validation_data=(x_test, y_test))
score = model7.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 [==============================] - 29s 483us/step - loss: 2.1406 - acc: 0.182
4 - val_loss: 2.1229 - val_acc: 0.1850
Epoch 2/12
60000/60000 [==============================] - 28s 463us/step - loss: 2.1403 - acc: 0.181
2 - val_loss: 2.1250 - val_acc: 0.1903
Epoch 3/12
60000/60000 [==============================] - 28s 462us/step - loss: 2.1406 - acc: 0.182
6 - val_loss: 2.1245 - val_acc: 0.1856
Epoch 4/12
60000/60000 [==============================] - 28s 467us/step - loss: 2.1403 - acc: 0.181
9 - val_loss: 2.1243 - val_acc: 0.1856
Epoch 5/12
60000/60000 [==============================] - 28s 464us/step - loss: 2.1398 - acc: 0.183
2 - val_loss: 2.1243 - val_acc: 0.1849
Epoch 6/12
60000/60000 [==============================] - 28s 462us/step - loss: 2.1408 - acc: 0.183
4 - val_loss: 2.1240 - val_acc: 0.1856
Epoch 7/12
60000/60000 [==============================] - 28s 464us/step - loss: 2.1401 - acc: 0.182
9 - val_loss: 2.1243 - val_acc: 0.1858
Epoch 8/12
60000/60000 [==============================] - 28s 465us/step - loss: 2.1397 - acc: 0.182
8 - val_loss: 2.1246 - val_acc: 0.1856
Epoch 9/12
60000/60000 [==============================] - 28s 464us/step - loss: 2.1404 - acc: 0.184
2 - val_loss: 2.1232 - val_acc: 0.1857
Epoch 10/12
60000/60000 [==============================] - 28s 462us/step - loss: 2.1406 - acc: 0.184
2 - val_loss: 2.1243 - val_acc: 0.1903
```

```
Epoch 11/12
60000/60000 [==============================] - 28s 462us/step - loss: 2.1409 - acc: 0.182
9 - val_loss: 2.1257 - val_acc: 0.1850
Epoch 12/12
60000/60000 [==============================] - 28s 464us/step - loss: 2.1400 - acc: 0.181
6 - val_loss: 2.1231 - val_acc: 0.1849
Test loss: 2.123111280250549
Test accuracy: 0.1849
```

In [38]:

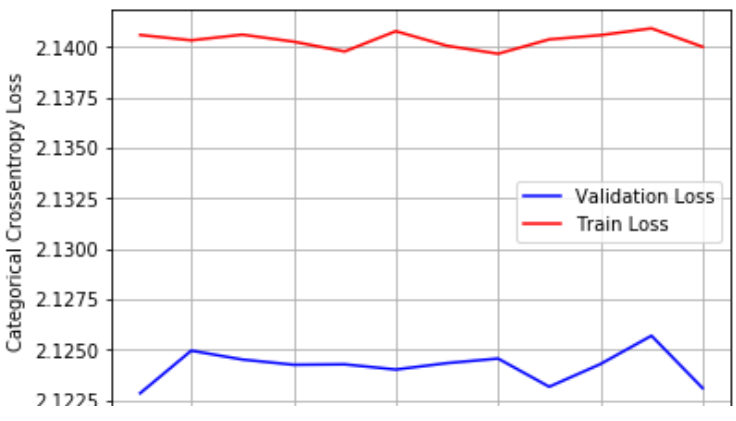
```
model7.summary()
```

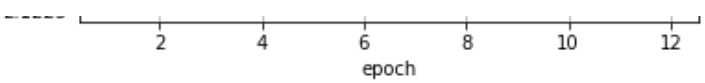
```
Model: "sequential_17"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_52 (Conv2D)           (None, 28, 28, 256)       2560
_________________________________________________________________
max_pooling2d_43 (MaxPooling (None, 14, 14, 256)       0
_________________________________________________________________
conv2d_53 (Conv2D)           (None, 14, 14, 128)       295040
_________________________________________________________________
max_pooling2d_44 (MaxPooling (None, 7, 7, 128)         0
_________________________________________________________________
conv2d_54 (Conv2D)           (None, 7, 7, 64)          73792
_________________________________________________________________
max_pooling2d_45 (MaxPooling (None, 3, 3, 64)          0
_________________________________________________________________
conv2d_55 (Conv2D)           (None, 3, 3, 32)          18464
_________________________________________________________________
conv2d_56 (Conv2D)           (None, 3, 3, 16)          4624
_________________________________________________________________
flatten_11 (Flatten)         (None, 144)               0
_________________________________________________________________
dense_21 (Dense)             (None, 32)                4640
_________________________________________________________________
dense_22 (Dense)             (None, 10)                330
=================================================================
Total params: 399,450
Trainable params: 399,450
Non-trainable params: 0
_________________________________________________________________
```

In [39]:

```
score = model7.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')
x = list(range(1,epochs+1))
vl = inspect.history['val_loss']
tl = inspect.history['loss']
plt_dynamic(x, vl, tl, ax)
```

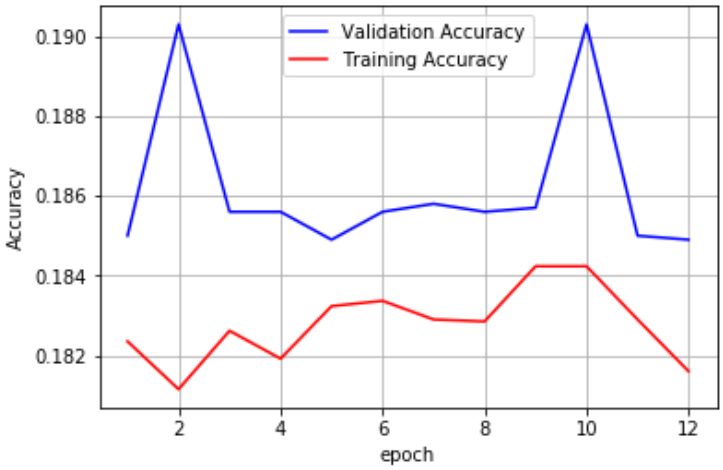
```
Test score: 2.3014822479248047
Test accuracy: 0.0977
```





In [40]:

```
fig,ax = plt.subplots(1,1)
ax.set_xlabel('epoch') ; ax.set_ylabel('Accuracy')
x = list(range(1,epochs+1))
vacc = inspect.history['val_acc']
tacc = inspect.history['acc']
plt_dynamic1(x, vacc, tacc, ax)
```



17. 5 CONVOLUTIONAL LAYERS (MAX POOLING,BATCHNORM AND DROPOUT(0.5 and 0.6) 3X3 FILTER,SGD OPTIMISER,RELU Activation,RANDOM UNIFORM INITIALISER)

In [43]:

```
from keras.layers.normalization import BatchNormalization
model8 = Sequential()
#1ST
model8.add(Conv2D(256, kernel_size=(3, 3),
                 activation='relu',
                 input_shape=input_shape,padding="same",kernel_initializer='random_unifo
rm'))
model8.add(BatchNormalization())
model8.add(MaxPooling2D(pool_size=(2, 2)))
model8.add(Dropout(0.6))


#2ND
model8.add(Conv2D(128, (3, 3), activation='relu',padding="same",kernel_initializer='rand
om_uniform'))

model8.add(BatchNormalization())
model8.add(MaxPooling2D(pool_size=(2, 2)))
model8.add(Dropout(0.5))


#3RD
model8.add(Conv2D(64, (3, 3), activation='relu',padding="same",kernel_initializer='rando
m_uniform'))
model8.add(BatchNormalization())
model8.add(MaxPooling2D(pool_size=(2, 2)))
model8.add(Dropout(0.5))

#4TH
model8.add(Conv2D(32, (3, 3), activation='relu',padding="same",kernel_initializer='rando
m_uniform'))
model8.add(BatchNormalization())
model8.add(MaxPooling2D(pool_size=(2, 2)))
model8.add(Dropout(0.5))

#5TH
```

```
model8.add(Conv2D(16, (3, 3), activation='relu',padding="same",kernel_initializer='rando
m_uniform'))
model8.add(BatchNormalization())
#model8.add(MaxPooling2D(pool_size=(2, 2)))
model8.add(Dropout(0.5))

model8.add(Flatten())
model8.add(Dense(32, activation='relu'))

model8.add(Dense(num_classes, activation='softmax'))

model8.compile(loss=keras.losses.categorical_crossentropy,
              optimizer=keras.optimizers.SGD(),
              metrics=['accuracy'])

inspect = model8.fit(x_train, y_train,
          batch_size=batch_size,
          epochs=epochs,
          verbose=1,
          validation_data=(x_test, y_test))
score = model8.evaluate(x_test, y_test, verbose=0)
print('Test loss:', score[0])
print('Test accuracy:', score[1])
```

```
WARNING:tensorflow:Large dropout rate: 0.6 (>0.5). In TensorFlow 2.x, dropout() uses drop
out rate instead of keep_prob. Please ensure that this is intended.
Train on 60000 samples, validate on 10000 samples
Epoch 1/12
60000/60000 [==============================] - 33s 544us/step - loss: 2.2076 - acc: 0.194
6 - val_loss: 2.9449 - val_acc: 0.1193
Epoch 2/12
60000/60000 [==============================] - 30s 497us/step - loss: 1.7290 - acc: 0.378
5 - val_loss: 1.9839 - val_acc: 0.3266
Epoch 3/12
60000/60000 [==============================] - 30s 497us/step - loss: 1.4061 - acc: 0.487
8 - val_loss: 1.3686 - val_acc: 0.5544
Epoch 4/12
60000/60000 [==============================] - 30s 505us/step - loss: 1.1591 - acc: 0.578
2 - val_loss: 0.8924 - val_acc: 0.7431
Epoch 5/12
60000/60000 [==============================] - 30s 503us/step - loss: 0.9946 - acc: 0.643
6 - val_loss: 0.6976 - val_acc: 0.7971
Epoch 6/12
60000/60000 [==============================] - 30s 505us/step - loss: 0.8827 - acc: 0.683
2 - val_loss: 0.5779 - val_acc: 0.8454
Epoch 7/12
60000/60000 [==============================] - 30s 503us/step - loss: 0.7983 - acc: 0.718
3 - val_loss: 0.4070 - val_acc: 0.8990
Epoch 8/12
60000/60000 [==============================] - 30s 504us/step - loss: 0.7332 - acc: 0.744
7 - val_loss: 0.3589 - val_acc: 0.9148
Epoch 9/12
60000/60000 [==============================] - 30s 504us/step - loss: 0.6853 - acc: 0.760
0 - val_loss: 0.3746 - val_acc: 0.8940
Epoch 10/12
60000/60000 [==============================] - 30s 505us/step - loss: 0.6431 - acc: 0.778
0 - val_loss: 0.2435 - val_acc: 0.9396
Epoch 11/12
60000/60000 [==============================] - 30s 503us/step - loss: 0.6061 - acc: 0.792
1 - val_loss: 0.2162 - val_acc: 0.9463
Epoch 12/12
60000/60000 [==============================] - 30s 504us/step - loss: 0.5743 - acc: 0.804
2 - val_loss: 0.1933 - val_acc: 0.9499
Test loss: 0.1933117022037506
Test accuracy: 0.9499
```

In [45]:

```
model8.summary()
```

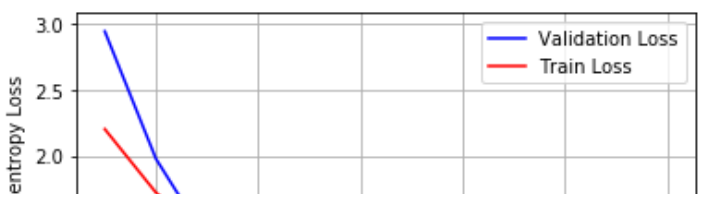
```
Model: "sequential_20"
_________________________________________________________________
```

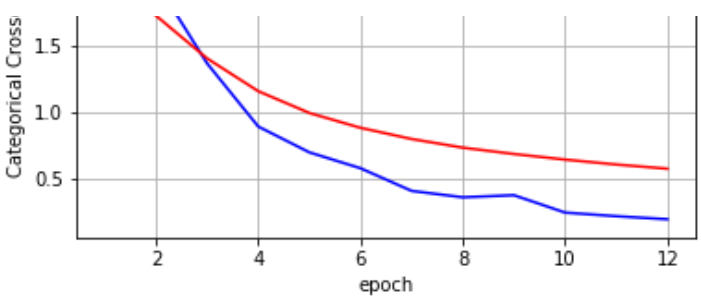
```
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_67 (Conv2D)           (None, 28, 28, 256)       2560
_________________________________________________________________
batch_normalization_38 (Batc (None, 28, 28, 256)       1024
_________________________________________________________________
max_pooling2d_55 (MaxPooling (None, 14, 14, 256)       0
_________________________________________________________________
dropout_32 (Dropout)         (None, 14, 14, 256)       0
_________________________________________________________________
conv2d_68 (Conv2D)           (None, 14, 14, 128)       295040
_________________________________________________________________
batch_normalization_39 (Batc (None, 14, 14, 128)       512
_________________________________________________________________
max_pooling2d_56 (MaxPooling (None, 7, 7, 128)         0
_________________________________________________________________
dropout_33 (Dropout)         (None, 7, 7, 128)         0
_________________________________________________________________
conv2d_69 (Conv2D)           (None, 7, 7, 64)          73792
_________________________________________________________________
batch_normalization_40 (Batc (None, 7, 7, 64)          256
_________________________________________________________________
max_pooling2d_57 (MaxPooling (None, 3, 3, 64)          0
_________________________________________________________________
dropout_34 (Dropout)         (None, 3, 3, 64)          0
_________________________________________________________________
conv2d_70 (Conv2D)           (None, 3, 3, 32)          18464
_________________________________________________________________
batch_normalization_41 (Batc (None, 3, 3, 32)          128
_________________________________________________________________
max_pooling2d_58 (MaxPooling (None, 1, 1, 32)          0
_________________________________________________________________
dropout_35 (Dropout)         (None, 1, 1, 32)          0
_________________________________________________________________
conv2d_71 (Conv2D)           (None, 1, 1, 16)          4624
_________________________________________________________________
batch_normalization_42 (Batc (None, 1, 1, 16)          64
_________________________________________________________________
dropout_36 (Dropout)         (None, 1, 1, 16)          0
_________________________________________________________________
flatten_13 (Flatten)         (None, 16)                0
_________________________________________________________________
dense_25 (Dense)             (None, 32)                544
_________________________________________________________________
dense_26 (Dense)             (None, 10)                330
=================================================================
Total params: 397,338
Trainable params: 396,346
Non-trainable params: 992
_________________________________________________________________
```

In [46]:

```
score = model8.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')
x = list(range(1,epochs+1))
vl = inspect.history['val_loss']
tl = inspect.history['loss']
plt_dynamic(x, vl, tl, ax)
```

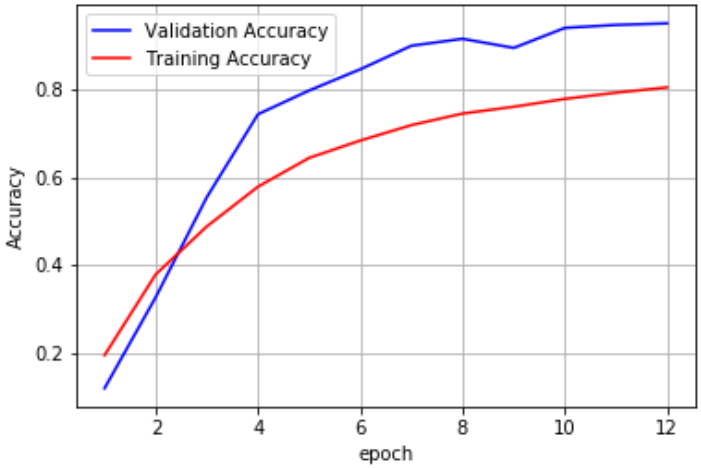
```
Test score: 0.1933117022037506
Test accuracy: 0.9499
```





In [47]:

```
fig,ax = plt.subplots(1,1)
ax.set_xlabel('epoch') ; ax.set_ylabel('Accuracy')
x = list(range(1,epochs+1))
vacc = inspect.history['val_acc']
tacc = inspect.history['acc']
plt_dynamic1(x, vacc, tacc, ax)
```



18. 5 CONVOLUTIONAL LAYERS (MAX POOLING,DROPOUT, 3X3 FILTER,Adamax OPTIMISER,TANH Activation,Orthogonal INITIALISER)

In [48]:

```
from keras.layers.normalization import BatchNormalization
model9 = Sequential()
#1ST
model9.add(Conv2D(256, kernel_size=(3, 3),
                 activation='relu',
                 input_shape=input_shape,padding="same",kernel_initializer='random_unifo
rm'))
#model8.add(BatchNormalization())
model9.add(MaxPooling2D(pool_size=(2, 2)))
model9.add(Dropout(0.3))


#2ND
model9.add(Conv2D(128, (3, 3), activation='relu',padding="same",kernel_initializer='rand
om_uniform'))

#model8.add(BatchNormalization())
model9.add(MaxPooling2D(pool_size=(2, 2)))
model9.add(Dropout(0.3))


#3RD
model9.add(Conv2D(64, (3, 3), activation='relu',padding="same",kernel_initializer='rando
m_uniform'))
#model8.add(BatchNormalization())
model9.add(MaxPooling2D(pool_size=(2, 2)))
model9.add(Dropout(0.3))

#4TH
```

```
model9.add(Conv2D(32, (3, 3), activation='relu',padding="same",kernel_initializer='rando
m_uniform'))
#model8.add(BatchNormalization())
model9.add(MaxPooling2D(pool_size=(2, 2)))
model9.add(Dropout(0.3))

#5TH
model9.add(Conv2D(16, (3, 3), activation='relu',padding="same",kernel_initializer='rando
m_uniform'))
model9.add(BatchNormalization())
#model8.add(MaxPooling2D(pool_size=(2, 2)))
model9.add(Dropout(0.3))

model9.add(Flatten())
model9.add(Dense(32, activation='relu'))

model9.add(Dense(num_classes, activation='softmax'))

model9.compile(loss=keras.losses.categorical_crossentropy,
              optimizer=keras.optimizers.Adamax(),
              metrics=['accuracy'])

inspect = model9.fit(x_train, y_train,
          batch_size=batch_size,
          epochs=epochs,
          verbose=1,
          validation_data=(x_test, y_test))
score = model9.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 [==============================] - 25s 414us/step - loss: 1.0174 - acc: 0.660
7 - val_loss: 0.1634 - val_acc: 0.9638
Epoch 2/12
60000/60000 [==============================] - 22s 375us/step - loss: 0.2846 - acc: 0.922
4 - val_loss: 0.0631 - val_acc: 0.9820
Epoch 3/12
60000/60000 [==============================] - 23s 375us/step - loss: 0.1986 - acc: 0.945
6 - val_loss: 0.0465 - val_acc: 0.9864
Epoch 4/12
60000/60000 [==============================] - 23s 378us/step - loss: 0.1543 - acc: 0.958
2 - val_loss: 0.0371 - val_acc: 0.9893
Epoch 5/12
60000/60000 [==============================] - 22s 373us/step - loss: 0.1346 - acc: 0.964
1 - val_loss: 0.0367 - val_acc: 0.9903
Epoch 6/12
60000/60000 [==============================] - 22s 375us/step - loss: 0.1244 - acc: 0.967
5 - val_loss: 0.0391 - val_acc: 0.9895
Epoch 7/12
60000/60000 [==============================] - 22s 372us/step - loss: 0.1139 - acc: 0.969
8 - val_loss: 0.0314 - val_acc: 0.9907
Epoch 8/12
60000/60000 [==============================] - 22s 373us/step - loss: 0.1030 - acc: 0.971
4 - val_loss: 0.0270 - val_acc: 0.9925
Epoch 9/12
60000/60000 [==============================] - 22s 370us/step - loss: 0.0973 - acc: 0.974
3 - val_loss: 0.0276 - val_acc: 0.9917
Epoch 10/12
60000/60000 [==============================] - 22s 368us/step - loss: 0.0952 - acc: 0.975
8 - val_loss: 0.0274 - val_acc: 0.9920
Epoch 11/12
60000/60000 [==============================] - 22s 369us/step - loss: 0.0894 - acc: 0.976
6 - val_loss: 0.0249 - val_acc: 0.9927
Epoch 12/12
60000/60000 [==============================] - 22s 370us/step - loss: 0.0891 - acc: 0.976
4 - val_loss: 0.0231 - val_acc: 0.9931
Test loss: 0.023112671578422304
Test accuracy: 0.9931
```

In [49]:

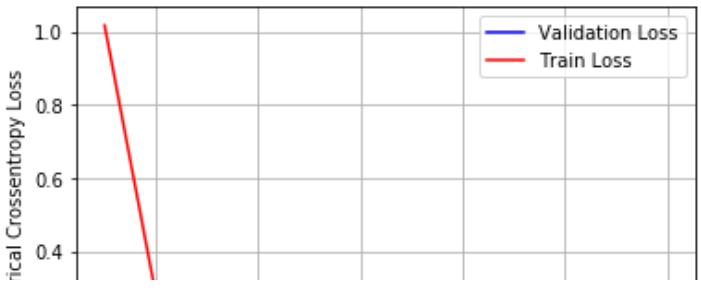
```
model9.summary()
```

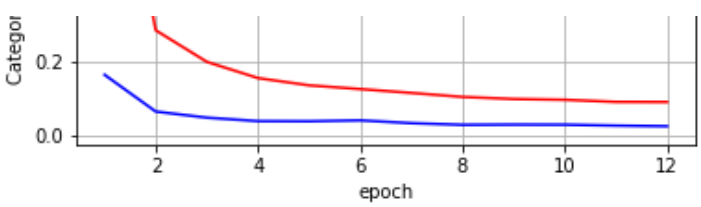
```
Model: "sequential_21"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_72 (Conv2D)           (None, 28, 28, 256)       2560
_________________________________________________________________
max_pooling2d_59 (MaxPooling (None, 14, 14, 256)       0
_________________________________________________________________
dropout_37 (Dropout)         (None, 14, 14, 256)       0
_________________________________________________________________
conv2d_73 (Conv2D)           (None, 14, 14, 128)       295040
_________________________________________________________________
max_pooling2d_60 (MaxPooling (None, 7, 7, 128)         0
_________________________________________________________________
dropout_38 (Dropout)         (None, 7, 7, 128)         0
_________________________________________________________________
conv2d_74 (Conv2D)           (None, 7, 7, 64)          73792
_________________________________________________________________
max_pooling2d_61 (MaxPooling (None, 3, 3, 64)          0
_________________________________________________________________
dropout_39 (Dropout)         (None, 3, 3, 64)          0
_________________________________________________________________
conv2d_75 (Conv2D)           (None, 3, 3, 32)          18464
_________________________________________________________________
max_pooling2d_62 (MaxPooling (None, 1, 1, 32)          0
_________________________________________________________________
dropout_40 (Dropout)         (None, 1, 1, 32)          0
_________________________________________________________________
conv2d_76 (Conv2D)           (None, 1, 1, 16)          4624
_________________________________________________________________
batch_normalization_43 (Batc (None, 1, 1, 16)          64
_________________________________________________________________
dropout_41 (Dropout)         (None, 1, 1, 16)          0
_________________________________________________________________
flatten_14 (Flatten)         (None, 16)                0
_________________________________________________________________
dense_27 (Dense)             (None, 32)                544
_________________________________________________________________
dense_28 (Dense)             (None, 10)                330
=================================================================
Total params: 395,418
Trainable params: 395,386
Non-trainable params: 32
_________________________________________________________________
```

In [50]:

```
score = model9.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')
x = list(range(1,epochs+1))
vl = inspect.history['val_loss']
tl = inspect.history['loss']
plt_dynamic(x, vl, tl, ax)
```

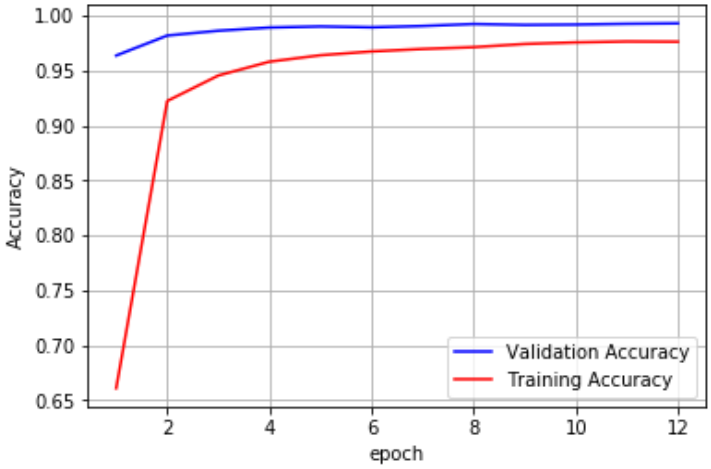
```
Test score: 0.023112671578422304
Test accuracy: 0.9931
```





In [51]:

```
fig,ax = plt.subplots(1,1)
ax.set_xlabel('epoch') ; ax.set_ylabel('Accuracy')
x = list(range(1,epochs+1))
vacc = inspect.history['val_acc']
tacc = inspect.history['acc']
plt_dynamic1(x, vacc, tacc, ax)
```



Conclusions

In [0]:

```
from prettytable import PrettyTable
f='Not present'
t='Present'
t25='Present-(Rate=0.25)'
t5='Present-(Rate=0.5)'
t2='Present-(Rate=0.2)'
test_scr=[0.031,0.023,0.032,0.045,0.023,0.033,0.032,0.038,0.025]
test_acc=[0.9897,0.9936,0.9896,0.9874,0.9927,0.9927,0.9913,0.99,0.9938]
d=[t25,f,t5,f,t5,f,f,t5,t2]
b=[f,t,t,t,t,t,t,t,t]
l=[2,2,2,3,3,3,5,5,7]
sno =[1,2,3,4,5,6,7,8,9]
```

In [0]:

```
table = PrettyTable()
table.add_column('S-NO',sno)
table.add_column("No of Convolution Layers",l)
table.add_column("Dropout Present",d)
table.add_column("Batch Norm Present",b)
table.add_column("Test Loss",test_scr)
table.add_column("Test Acuracy",test_acc)
```

In [0]:

```
print('In the pretty table Dropout is considered only of the convolutional layers.Some mo
dels are having a dense layer with dropout value 0.5 and some doesnt have any dropout rat
e to their dense layer')
print(table)
```

```
In the pretty table Dropout is considered only of the convolutional layers.Some models ar
e having a dense layer with dropout value 0.5 and some doesnt have any dropout rate to th
eir dense layer
```

```
+------+--------------------------+--------------------+-------------------+---------
--+--------------+
| S-NO | No of Convolution Layers |   Dropout Present  | Batch Norm Present | Test Loss
| Test Acuracy |
+------+--------------------------+--------------------+-------------------+---------
--+--------------+
|  1   |            2             | Present-(Rate=0.25) |    Not present    |   0.031
|    0.9897    |
|  2   |            2             |     Not present    |      Present      |   0.023
|    0.9936    |
|  3   |            2             |  Present-(Rate=0.5) |      Present      |   0.032
|    0.9896    |
|  4   |            3             |     Not present    |      Present      |   0.045
|    0.9874    |
|  5   |            3             |  Present-(Rate=0.5) |      Present      |   0.023
|    0.9927    |
|  6   |            3             |     Not present    |      Present      |   0.033
|    0.9927    |
|  7   |            5             |     Not present    |      Present      |   0.032
|    0.9913    |
|  8   |            5             |  Present-(Rate=0.5) |      Present      |   0.038
|     0.99     |
|  9   |            7             |  Present-(Rate=0.2) |      Present      |   0.025
|    0.9938    |
+------+--------------------------+--------------------+-------------------+---------
--+--------------+
```

In [0]:

```
F='Not present'
T='Present'
T5 = 'Present-(Rate = 0.5)'
T3 = 'Present-(Rate = 0.3)'
T4 = 'Present-(Rate = 0.4)'
Optimiser = ['AdaDelta','AdaDelta','AdaDelta','AdaDelta','RMSProp','RMSProp','RMSProp','S
GD','Adamax']
Activation =['Relu','Tanh','Tanh','Sigmoid','Elu','Tanh','Tanh','Relu','Relu']
Initialiser = ['Random_Uniform','Random_Uniform','Orthogonal','Orthogonal','Zeros','Ones
','Random_Uniform','Random_Uniform','Random_Uniform']
Filter_size= [2,2,2,3,3,3,3,3,3]
layers =[3,3,3,3,5,5,5,5,5]
d=[F,F,T4,F,F,F,F,T5,T3]
b=[F,F,T,F,T,T,F,T,F]
test_scr=[0.044,0.063,0.075,2.300,2.301,2.124,2.301,0.193,0.023]
test_acc=[0.986,0.982,0.977,0.113,0.113,0.185,0.097,0.949,0.993]
sno =[1,2,3,4,5,6,7,8,9]
from prettytable import PrettyTable
table = PrettyTable()
table.add_column('S-NO',sno)
table.add_column("No of Convolution Layers",layers)
table.add_column("Optimizer",Optimiser)
table.add_column("Activation fn",Activation)
table.add_column("Initializer",Initialiser)
table.add_column("Size of the filter",Filter_size)
table.add_column("Dropout Present",d)
table.add_column("Batch Norm Present",b)
table.add_column("Test Loss",test_scr)
table.add_column("Test Acuracy",test_acc)
```

In [54]:

```
print('Comparison table of models with different activation functions,intialisers,Optimis
ers other than those used in previous models')
print('In the pretty table Dropout is considered only of the convolutional layers.Some mo
dels are having a dense layer with dropout value 0.5 and some doesnt have any dropout rat
e to their dense layer')
print(table)
```

```
Comparison table of models with different activation functions,intialisers,Optimisers oth
er than those used in previous models
In the pretty table Dropout is considered only of the convolutional layers.Some models ar
```

e having a dense layer with dropout value 0.5 and some doesnt have any dropout rate to th
eir dense layer

S-NO	No of Convolution Layers	Optimizer	Activation fn	Initializer	Size of the filter	Dropout Present	Batch Norm Present	Test Loss	Test Acuracy
1	3	AdaDelta	Relu	Random_Uniform	2	Not present	Not present	0.044	0.986
2	3	AdaDelta	Tanh	Random_Uniform	2	Not present	Not present	0.063	0.982
3	3	AdaDelta	Tanh	Orthogonal	2	Present-(Rate = 0.4)	Present	0.075	0.977
4	3	AdaDelta	Sigmoid	Orthogonal	3	Not present	Not present	2.3	0.113
5	5	RMSProp	Elu	Zeros	3	Not present	Present	2.301	0.113
6	5	RMSProp	Tanh	Ones	3	Not present	Present	2.124	0.185
7	5	RMSProp	Tanh	Random_Uniform	3	Not present	Not present	2.301	0.097
8	5	SGD	Relu	Random_Uniform	3	Present-(Rate = 0.5)	Present	0.193	0.949
9	5	Adamax	Relu	Random_Uniform	3	Present-(Rate = 0.3)	Not present	0.023	0.993

OBSERVATIONS

1. In this assignment , I started with loading the MNIST dataset and did some preprocessing on the data.

2. Later , I experimented training different CNN Architectures with Adam Optimiser. I experimented with Batch Normalisation and different values of Dropout.

3. Also , I tried other architectures with different kernal initialisers , activation functions and optimisers.

During this Assignment , i have observed the following :

-> All the CNN architectures with Adam optimiser achieved high accuracy (above 99 %)

-> AdaDelta optimiser gave 11 % accuracy with sigmoid activation and achieved 97-99% accuracies when tried with other activation functions

-> RMSProp optimiser failed to achieve good results, ended up with accuracy of just 10%-20% irrespective of combinations of different activation functions and initialisers.

-> SGD optimiser model started with low accuracy and then it improved gradually with number of epochs.It may achieve 99% like other good models if trained further for 5-10 epochs.

-> I believe the show stealer is Adamax optimiser model. It achieved whopping 99.3% test accuracy . It started with low accuracy at the earlier epochs and improved faster than SGD model gradually with number of epochs.