1 Autoencoder

Build and fit a convolutional autoencoder for the Fashion MNIST dataset.

- The components of this network will be many of the same pieces we’ve used with convolutional classification networks: Conv2D, MaxPooling, and so on.
- The encoder part of the network should run the input image through a few convolutional layers of your choice.
- The decoder part ofthe network will utilize UpSampling2D to get the representation back to the original image size.
- After training your network, visualize some examples of input images and their decoded reconstruction.

In [4]:
```
import tensorflow as tf
import matplotlib.pyplot as plt
from keras.datasets import fashion_mnist
from keras.utils import np_utils
%matplotlib inline
(x_train, y_train), (x_test, y_test) = fashion_mnist.load_data()


# Reshaping the array to 4-dims so that it can work with the Keras API
x_train = x_train.reshape(x_train.shape[0], 28, 28, 1)
x_test = x_test.reshape(x_test.shape[0], 28, 28, 1)
input_shape = (28, 28, 1)
# Making sure that the values are float so that we can get decimal points after division
x_train = x_train.astype('float32')
x_test = x_test.astype('float32')
# Normalizing the RGB codes by dividing it to the max RGB value.
x_train /= 255
x_test /= 255

#y_train = np_utils.to_categorical(y_train, 10)
#y_test = np_utils.to_categorical(y_test, 10)
print('x_train shape:', x_train.shape)
print('Number of images in x_train', x_train.shape[0])
print('Number of images in x_test', x_test.shape[0])
```

```
Downloading data from http://fashion-mnist.s3-website.eu-central-1.amazonaws.com/train-labels-idx1-ubyte.gz
32768/29515 [=================================] - 0s 8us/step
Downloading data from http://fashion-mnist.s3-website.eu-central-1.amazonaws.com/train-images-idx3-ubyte.gz
26427392/26421880 [==============================] - 4s 0us/step
Downloading data from http://fashion-mnist.s3-website.eu-central-1.amazonaws.com/t10k-labels-idx1-ubyte.gz
8192/5148 [===============================================] - 0s 0us/step
Downloading data from http://fashion-mnist.s3-website.eu-central-1.amazonaws.com/t10k-images-idx3-ubyte.gz
4423680/4422102 [==============================] - 2s 0us/step
x_train shape: (60000, 28, 28, 1)
Number of images in x_train 60000
Number of images in x_test 10000
```

In [3]:
```
from keras.layers import Input, Dense, Conv2D, MaxPooling2D, UpSampling2D
from keras.models import Model
from keras import backend as K

input_img = Input(shape=(28, 28, 1))  # adapt this if using `channels_first` image data format

x = Conv2D(32, (3, 3), activation='relu', padding='same')(input_img)
x = MaxPooling2D((2, 2), padding='same')(x)
x = Conv2D(16, (3, 3), activation='relu', padding='same')(x)
x = MaxPooling2D((2, 2), padding='same')(x)
x = Conv2D(8, (3, 3), activation='relu', padding='same')(x)
encoded = MaxPooling2D((2, 2), padding='same')(x)

# at this point the representation is (4, 4, 8) i.e. 128-dimensional

x = Conv2D(8, (3, 3), activation='relu', padding='same')(encoded)
x = UpSampling2D((2, 2))(x)
x = Conv2D(16, (3, 3), activation='relu', padding='same')(x)
x = UpSampling2D((2, 2))(x)
x = Conv2D(32, (3, 3), activation='relu')(x)
x = UpSampling2D((2, 2))(x)
decoded = Conv2D(1, (3, 3), activation='sigmoid', padding='same')(x)

autoencoder = Model(input_img, decoded)
autoencoder.summary()
autoencoder.compile(optimizer='adadelta', loss='binary_crossentropy')
```

```
Layer (type)                 Output Shape              Param #
=================================================================
input_1 (InputLayer)         (None, 28, 28, 1)         0
_________________________________________________________________
conv2d_1 (Conv2D)            (None, 28, 28, 32)        320
_________________________________________________________________
max_pooling2d_1 (MaxPooling2 (None, 14, 14, 32)        0
_________________________________________________________________
conv2d_2 (Conv2D)            (None, 14, 14, 16)        4624
_________________________________________________________________
max_pooling2d_2 (MaxPooling2 (None, 7, 7, 16)          0
_________________________________________________________________
conv2d_3 (Conv2D)            (None, 7, 7, 8)           1160
_________________________________________________________________
max_pooling2d_3 (MaxPooling2 (None, 4, 4, 8)           0
_________________________________________________________________
conv2d_4 (Conv2D)            (None, 4, 4, 8)           584
_________________________________________________________________
up_sampling2d_1 (UpSampling2 (None, 8, 8, 8)           0
_________________________________________________________________
conv2d_5 (Conv2D)            (None, 8, 8, 16)          1168
_________________________________________________________________
up_sampling2d_2 (UpSampling2 (None, 16, 16, 16)        0
_________________________________________________________________
conv2d_6 (Conv2D)            (None, 14, 14, 32)        4640
_________________________________________________________________
up_sampling2d_3 (UpSampling2 (None, 28, 28, 32)        0
_________________________________________________________________
conv2d_7 (Conv2D)            (None, 28, 28, 1)         289
=================================================================
Total params: 12,785
Trainable params: 12,785
Non-trainable params: 0
_________________________________________________________________
```

In [4]:
```
from keras.callbacks import EarlyStopping
eary_stopping = EarlyStopping(
    monitor='val_loss',
    min_delta=0,
    patience=10,
    verbose=1,
    mode='auto')

callbacks = [eary_stopping]

model = autoencoder.fit(x_train, x_train,
                                      epochs=100,
                                      batch_size=128,
                                      validation_data=(x_test, x_test),
                                      callbacks=callbacks)
```

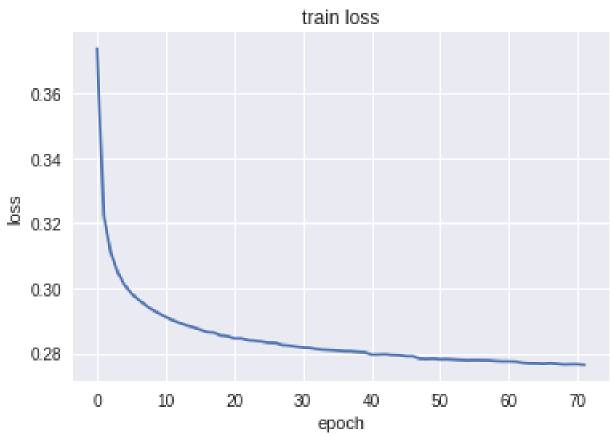
```
Train on 60000 samples, validate on 10000 samples
Epoch 1/100
60000/60000 [==============================] - 11s 186us/step - loss: 0.3738 - val_loss: 0.3339
Epoch 2/100
60000/60000 [==============================] - 7s 122us/step - loss: 0.3223 - val_loss: 0.3128
Epoch 3/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.3111 - val_loss: 0.3139
Epoch 4/100
60000/60000 [==============================] - 7s 122us/step - loss: 0.3051 - val_loss: 0.3076
Epoch 5/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.3011 - val_loss: 0.2980
Epoch 6/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.2985 - val_loss: 0.3016
Epoch 7/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.2966 - val_loss: 0.3000
Epoch 8/100
60000/60000 [==============================] - 7s 122us/step - loss: 0.2950 - val_loss: 0.2934
Epoch 9/100
60000/60000 [==============================] - 7s 122us/step - loss: 0.2935 - val_loss: 0.2961
Epoch 10/100
60000/60000 [==============================] - 7s 122us/step - loss: 0.2923 - val_loss: 0.2929
Epoch 11/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.2912 - val_loss: 0.2916
Epoch 12/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.2902 - val_loss: 0.2967
Epoch 13/100
60000/60000 [==============================] - 7s 122us/step - loss: 0.2894 - val_loss: 0.2888
Epoch 14/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.2886 - val_loss: 0.2904
Epoch 15/100
60000/60000 [==============================] - 7s 122us/step - loss: 0.2880 - val_loss: 0.2867
Epoch 16/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.2873 - val_loss: 0.2889
Epoch 17/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.2865 - val_loss: 0.2897
Epoch 18/100
60000/60000 [==============================] - 7s 122us/step - loss: 0.2864 - val_loss: 0.2852
Epoch 19/100
60000/60000 [==============================] - 7s 122us/step - loss: 0.2855 - val_loss: 0.2860
Epoch 20/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.2853 - val_loss: 0.2852
Epoch 21/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.2846 - val_loss: 0.2854
Epoch 22/100
60000/60000 [==============================] - 7s 122us/step - loss: 0.2846 - val_loss: 0.2852
Epoch 23/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.2840 - val_loss: 0.2845
Epoch 24/100
60000/60000 [==============================] - 7s 122us/step - loss: 0.2838 - val_loss: 0.2857
Epoch 25/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.2836 - val_loss: 0.2856
Epoch 26/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.2832 - val_loss: 0.2834
Epoch 27/100
```

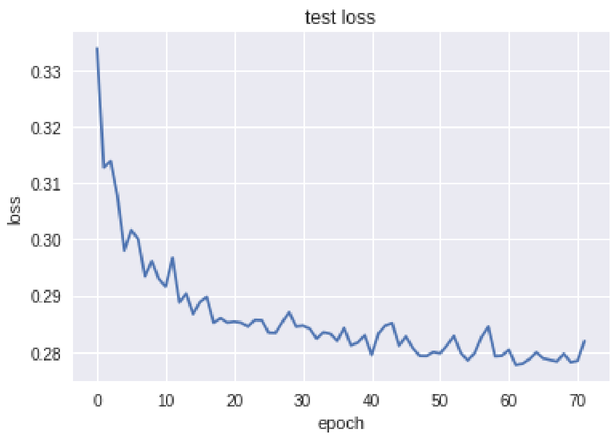
```
60000/60000 [==============================] - 7s 121us/step - loss: 0.2832 - val_loss: 0.2834
Epoch 28/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.2825 - val_loss: 0.2853
Epoch 29/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.2824 - val_loss: 0.2871
Epoch 30/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.2821 - val_loss: 0.2845
Epoch 31/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.2818 - val_loss: 0.2847
Epoch 32/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.2817 - val_loss: 0.2841
Epoch 33/100
60000/60000 [==============================] - 7s 122us/step - loss: 0.2813 - val_loss: 0.2824
Epoch 34/100
60000/60000 [==============================] - 7s 122us/step - loss: 0.2811 - val_loss: 0.2835
Epoch 35/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.2810 - val_loss: 0.2832
Epoch 36/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.2808 - val_loss: 0.2819
Epoch 37/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.2807 - val_loss: 0.2843
Epoch 38/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.2806 - val_loss: 0.2811
Epoch 39/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.2804 - val_loss: 0.2817
Epoch 40/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.2803 - val_loss: 0.2830
Epoch 41/100
60000/60000 [==============================] - 7s 122us/step - loss: 0.2796 - val_loss: 0.2795
Epoch 42/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.2796 - val_loss: 0.2833
Epoch 43/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.2797 - val_loss: 0.2847
Epoch 44/100
60000/60000 [==============================] - 7s 120us/step - loss: 0.2795 - val_loss: 0.2851
Epoch 45/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.2794 - val_loss: 0.2811
Epoch 46/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.2791 - val_loss: 0.2828
Epoch 47/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.2791 - val_loss: 0.2807
Epoch 48/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.2783 - val_loss: 0.2793
Epoch 49/100
60000/60000 [==============================] - 7s 122us/step - loss: 0.2782 - val_loss: 0.2793
Epoch 50/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.2783 - val_loss: 0.2800
Epoch 51/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.2781 - val_loss: 0.2797
Epoch 52/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.2782 - val_loss: 0.2812
Epoch 53/100
60000/60000 [==============================] - 7s 122us/step - loss: 0.2780 - val_loss: 0.2828
Epoch 54/100
```

```
60000/60000 [==============================] - 7s 121us/step - loss: 0.2779 - val_loss: 0.2798
Epoch 55/100
60000/60000 [==============================] - 7s 122us/step - loss: 0.2778 - val_loss: 0.2785
Epoch 56/100
60000/60000 [==============================] - 7s 122us/step - loss: 0.2779 - val_loss: 0.2798
Epoch 57/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.2778 - val_loss: 0.2826
Epoch 58/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.2778 - val_loss: 0.2845
Epoch 59/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.2776 - val_loss: 0.2792
Epoch 60/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.2775 - val_loss: 0.2793
Epoch 61/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.2775 - val_loss: 0.2804
Epoch 62/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.2774 - val_loss: 0.2777
Epoch 63/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.2771 - val_loss: 0.2779
Epoch 64/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.2769 - val_loss: 0.2787
Epoch 65/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.2769 - val_loss: 0.2799
Epoch 66/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.2768 - val_loss: 0.2789
Epoch 67/100
60000/60000 [==============================] - 7s 122us/step - loss: 0.2769 - val_loss: 0.2786
Epoch 68/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.2768 - val_loss: 0.2783
Epoch 69/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.2765 - val_loss: 0.2797
Epoch 70/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.2766 - val_loss: 0.2781
Epoch 71/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.2766 - val_loss: 0.2784
Epoch 72/100
60000/60000 [==============================] - 7s 121us/step - loss: 0.2764 - val_loss: 0.2819
Epoch 00072: early stopping
```

In [5]:
```
# Evaluate

plt.plot(model.history['loss'])
plt.ylabel('loss')
plt.xlabel('epoch')
plt.title('train loss')
plt.show()
plt.plot(model.history['val_loss'])
plt.ylabel('loss')
plt.xlabel('epoch')
plt.title('test loss')
plt.show()
```





In [6]:
```
decoded_imgs = autoencoder.predict(x_test)

n = 10
plt.figure(figsize=(20, 4))
for i in range(n):
    # display original
    ax = plt.subplot(2, n, i+1)
    plt.imshow(x_test[i].reshape(28, 28))
    plt.gray()
    ax.get_xaxis().set_visible(False)
    ax.get_yaxis().set_visible(False)

    # display reconstruction
    ax = plt.subplot(2, n, i + n+1)
    plt.imshow(decoded_imgs[i].reshape(28, 28))
    plt.gray()
    ax.get_xaxis().set_visible(False)
    ax.get_yaxis().set_visible(False)
plt.show()
```

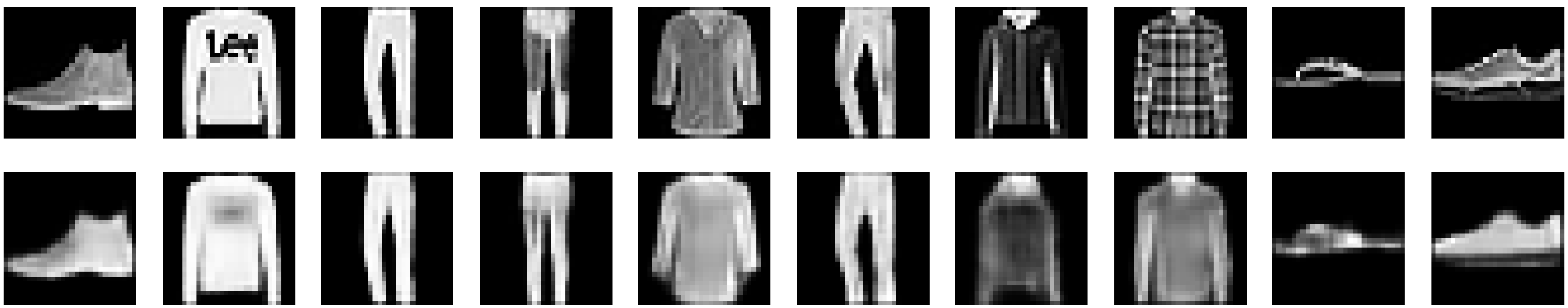


Image Classification

2.1Deep CNN

Build a deep CNN to classify the images.

- Provide a brief description of the architectural choices you've made: kernel sizes, strides, padding, network depth.
- Train your network end-to-end. Report on your model's performance on training set and test set.

In [11]:

```
import tensorflow as tf
(x_train, y_train), (x_test, y_test) = fashion_mnist.load_data()
# Reshaping the array to 4-dims so that it can work with the Keras API
x_train = x_train.reshape(x_train.shape[0], 28, 28, 1)
x_test = x_test.reshape(x_test.shape[0], 28, 28, 1)
input_shape = (28, 28, 1)
# Making sure that the values are float so that we can get decimal points after division
x_train = x_train.astype('float32')
x_test = x_test.astype('float32')
# Normalizing the RGB codes by dividing it to the max RGB value.
x_train /= 255
x_test /= 255
print('x_train shape:', x_train.shape)
print('Number of images in x_train', x_train.shape[0])
print('Number of images in x_test', x_test.shape[0])
```

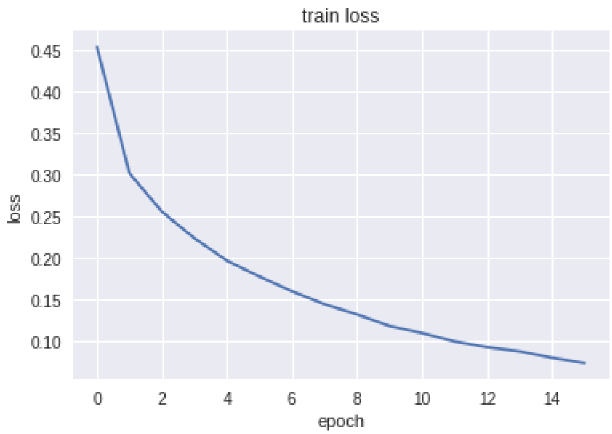
```
x_train shape: (60000, 28, 28, 1)
Number of images in x_train 60000
Number of images in x_test 10000
```

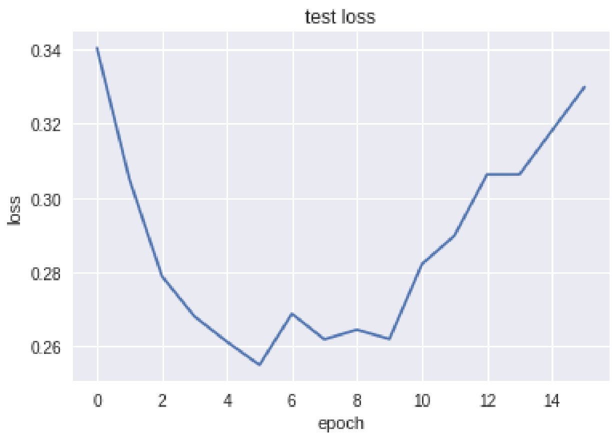
In [12]:
```
# Importing the required Keras modules containing model and layers
from keras.models import Sequential
from keras.layers import Dense, Conv2D, Dropout, Flatten, MaxPooling2D
from keras.callbacks import EarlyStopping
# Creating a Sequential Model and adding the layers
model = Sequential()
model.add(Conv2D(28, kernel_size=(3,3), input_shape=input_shape))
model.add(MaxPooling2D(pool_size=(2, 2)))
model.add(Flatten()) # Flattening the 2D arrays for fully connected layers
model.add(Dense(128, activation=tf.nn.relu))
model.add(Dropout(0.2))
model.add(Dense(10,activation=tf.nn.softmax))
model.summary()
model.compile(optimizer='adam',
              loss='sparse_categorical_crossentropy',
              metrics=['accuracy'])
eary_stopping = EarlyStopping(
    monitor='val_loss',
    min_delta=0,
    patience=10,
    verbose=1,
    mode='auto')
callbacks = [eary_stopping]
deep_cnn_model=model.fit(x=x_train,
                         y=y_train,
                         batch_size=64,
                         epochs=100,
                         validation_data=(x_test, y_test),
                         callbacks=callbacks)
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
conv2d_6 (Conv2D)            (None, 26, 26, 28)        280       
_________________________________________________________________
max_pooling2d_6 (MaxPooling2 (None, 13, 13, 28)        0         
_________________________________________________________________
flatten_6 (Flatten)          (None, 4732)              0         
_________________________________________________________________
dense_11 (Dense)             (None, 128)               605824    
_________________________________________________________________
dropout_6 (Dropout)          (None, 128)               0         
_________________________________________________________________
dense_12 (Dense)             (None, 10)                1290      
=================================================================
Total params: 607,394
Trainable params: 607,394
Non-trainable params: 0
_________________________________________________________________
Train on 60000 samples, validate on 10000 samples
Epoch 1/100
60000/60000 [==============================] - 8s 137us/step - loss: 0.4531 - acc: 0.8393 - val_loss: 0.3405 - val_acc: 0.8742
Epoch 2/100
60000/60000 [==============================] - 8s 128us/step - loss: 0.3014 - acc: 0.8908 - val_loss: 0.3050 - val_acc: 0.8886
Epoch 3/100
60000/60000 [==============================] - 8s 130us/step - loss: 0.2552 - acc: 0.9073 - val_loss: 0.2788 - val_acc: 0.8970
Epoch 4/100
60000/60000 [==============================] - 8s 129us/step - loss: 0.2235 - acc: 0.9180 - val_loss: 0.2680 - val_acc: 0.9009
Epoch 5/100
60000/60000 [==============================] - 8s 130us/step - loss: 0.1965 - acc: 0.9274 - val_loss: 0.2611 - val_acc: 0.9090
Epoch 6/100
60000/60000 [==============================] - 8s 129us/step - loss: 0.1775 - acc: 0.9352 - val_loss: 0.2549 - val_acc: 0.9101
Epoch 7/100
60000/60000 [==============================] - 8s 128us/step - loss: 0.1598 - acc: 0.9409 - val_loss: 0.2687 - val_acc: 0.9127
Epoch 8/100
60000/60000 [==============================] - 8s 127us/step - loss: 0.1443 - acc: 0.9463 - val_loss: 0.2618 - val_acc: 0.9137
Epoch 9/100
60000/60000 [==============================] - 8s 129us/step - loss: 0.1320 - acc: 0.9507 - val_loss: 0.2644 - val_acc: 0.9156
Epoch 10/100
60000/60000 [==============================] - 8s 129us/step - loss: 0.1180 - acc: 0.9556 - val_loss: 0.2618 - val_acc: 0.9135
Epoch 11/100
60000/60000 [==============================] - 8s 129us/step - loss: 0.1096 - acc: 0.9596 - val_loss: 0.2821 - val_acc: 0.9161
Epoch 12/100
60000/60000 [==============================] - 8s 129us/step - loss: 0.0995 - acc: 0.9628 - val_loss: 0.2898 - val_acc: 0.9153
Epoch 13/100
60000/60000 [==============================] - 8s 132us/step - loss: 0.0926 - acc: 0.9664 - val_loss: 0.3063 - val_acc: 0.9172
Epoch 14/100
60000/60000 [==============================] - 8s 129us/step - loss: 0.0876 - acc: 0.9677 - val_loss: 0.3063 - val_acc: 0.9154
Epoch 15/100
60000/60000 [==============================] - 8s 128us/step - loss: 0.0799 - acc: 0.9701 - val_loss: 0.3181 - val_acc: 0.9164
Epoch 16/100
60000/60000 [==============================] - 8s 129us/step - loss: 0.0735 - acc: 0.9727 - val_loss: 0.3299 - val_acc: 0.9164
Epoch 00016: early stopping
```

In [13]:
```
#Evaluate

plt.plot(deep_cnn_model.history['loss'])
plt.ylabel('loss')
plt.xlabel('epoch')
plt.title('train loss')
plt.show()
plt.plot(deep_cnn_model.history['val_loss'])
plt.ylabel('loss')
plt.xlabel('epoch')
plt.title('test loss')
plt.show()
```





2.2 Transfer Learning

Repeat the same task, but this time

- utilize a pre-trained network for the major- ity of your model.
- You should only train the final Dense layer, all other weights should be fixed.
- You can use whichever pre-trained backbone you like (ResNet, VGG, etc).
- Report on your model's performance on training set and test set.

In [7]:
```
from keras.preprocessing.image import img_to_array, array_to_img
from keras.applications.vgg16 import VGG16, preprocess_input, decode_predictions
import numpy as np
 # Transfer Learning

(x_train, y_train), (x_test, y_test) = fashion_mnist.load_data()

x_train = x_train.reshape(x_train.shape[0], 784).astype('float32')
x_test = x_test.reshape(x_test.shape[0], 784).astype('float32')

# Convert the images into 3 channels
x_train=np.dstack([x_train] * 3)
x_test=np.dstack([x_test]*3)

x_train = x_train.reshape(x_train.shape[0],28,28,3).astype('float32')
x_test = x_test.reshape(x_test.shape[0],28,28,3).astype('float32')

x_train = np.asarray([img_to_array(array_to_img(im, scale=False).resize((48,48))) for im in x_train])
x_test = np.asarray([img_to_array(array_to_img(im, scale=False).resize((48,48))) for im in x_test])


x_train = x_train / 255
x_test = x_test / 255

#label for each image
y_train = np_utils.to_categorical(y_train, 10)
y_test = np_utils.to_categorical(y_test, 10)


IMG_WIDTH = 48
IMG_HEIGHT = 48
IMG_DEPTH = 3
BATCH_SIZE = 16

x_train = preprocess_input(x_train)
x_test  = preprocess_input (x_test)

vgg = VGG16(weights='imagenet',
                  include_top=False,
                  input_shape=(IMG_HEIGHT, IMG_WIDTH, IMG_DEPTH)
                 )
vgg.summary()
```

```
Downloading data from https://github.com/fchollet/deep-learning-models/releases/download/v0.1/vgg16_weights_tf_dim_ordering_tf_ke
rnels_notop.h5
58892288/58889256 [==============================] - 6s 0us/step
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
input_1 (InputLayer)         (None, 48, 48, 3)         0         
_________________________________________________________________
block1_conv1 (Conv2D)        (None, 48, 48, 64)        1792      
_________________________________________________________________
block1_conv2 (Conv2D)        (None, 48, 48, 64)        36928     
_________________________________________________________________
block1_pool (MaxPooling2D)   (None, 24, 24, 64)        0         
_________________________________________________________________
block2_conv1 (Conv2D)        (None, 24, 24, 128)       73856     
_________________________________________________________________
block2_conv2 (Conv2D)        (None, 24, 24, 128)       147584    
_________________________________________________________________
block2_pool (MaxPooling2D)   (None, 12, 12, 128)       0         
_________________________________________________________________
block3_conv1 (Conv2D)        (None, 12, 12, 256)       295168    
_________________________________________________________________
block3_conv2 (Conv2D)        (None, 12, 12, 256)       590080    
_________________________________________________________________
block3_conv3 (Conv2D)        (None, 12, 12, 256)       590080    
_________________________________________________________________
block3_pool (MaxPooling2D)   (None, 6, 6, 256)         0         
_________________________________________________________________
block4_conv1 (Conv2D)        (None, 6, 6, 512)         1180160   
_________________________________________________________________
block4_conv2 (Conv2D)        (None, 6, 6, 512)         2359808   
_________________________________________________________________
block4_conv3 (Conv2D)        (None, 6, 6, 512)         2359808   
_________________________________________________________________
block4_pool (MaxPooling2D)   (None, 3, 3, 512)         0         
_________________________________________________________________
block5_conv1 (Conv2D)        (None, 3, 3, 512)         2359808   
_________________________________________________________________
block5_conv2 (Conv2D)        (None, 3, 3, 512)         2359808   
_________________________________________________________________
block5_conv3 (Conv2D)        (None, 3, 3, 512)         2359808   
_________________________________________________________________
block5_pool (MaxPooling2D)   (None, 1, 1, 512)         0         
=================================================================
Total params: 14,714,688
Trainable params: 14,714,688
Non-trainable params: 0
_________________________________________________________________
```

In [8]:
```
# Extracting features

train_features = vgg.predict(np.array(x_train), batch_size=BATCH_SIZE, verbose=1)
test_features = vgg.predict(np.array(x_test), batch_size=BATCH_SIZE, verbose=1)

# # Flatten extracted features

train_features_flat = np.reshape(train_features, (60000, 1*1*512))
test_features_flat = np.reshape(test_features, (10000, 1*1*512))
```

```
60000/60000 [==============================] - 68s 1ms/step
10000/10000 [==============================] - 11s 1ms/step
```

In [11]:
```
from keras.layers.advanced_activations import LeakyReLU
from keras.optimizers import SGD, Adam, RMSprop
from keras.models import Sequential, Model
from keras.layers import Embedding, LSTM, Dense, Dropout, Activation, Flatten, Input, Conv2D, MaxPooling2D, UpSampling2D

NB_TRAIN_SAMPLES = train_features_flat.shape[0]

trans_model = Sequential()
trans_model.add(Dense(512, activation='relu', input_dim=(1*1*512)))
trans_model.add(LeakyReLU(alpha=0.1))
trans_model.add(Dense(10, activation='softmax'))

trans_model.compile(
    loss='categorical_crossentropy',
    optimizer=Adam(),
    metrics=['acc'])

trans_model.summary()
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
dense_1 (Dense)              (None, 512)               262656    
_________________________________________________________________
leaky_re_lu_1 (LeakyReLU)    (None, 512)               0         
_________________________________________________________________
dense_2 (Dense)              (None, 10)                5130      
=================================================================
Total params: 267,786
Trainable params: 267,786
Non-trainable params: 0
_________________________________________________________________
```

In [12]:
```
from keras.callbacks import EarlyStopping
eary_stopping = EarlyStopping(
    monitor='loss',
    min_delta=0,
    patience=10,
    verbose=1,
    mode='auto')

callbacks = [eary_stopping]

transfer_model = trans_model.fit(
    train_features_flat,
    y_train,
    epochs=100,
    callbacks=callbacks
)
```

```
Epoch 1/100
60000/60000 [==============================] - 11s 176us/step - loss: 1.3918 - acc: 0.4879
Epoch 2/100
60000/60000 [==============================] - 10s 169us/step - loss: 1.0343 - acc: 0.6181
Epoch 3/100
60000/60000 [==============================] - 10s 169us/step - loss: 0.9538 - acc: 0.6492
Epoch 4/100
60000/60000 [==============================] - 10s 170us/step - loss: 0.9066 - acc: 0.6660
Epoch 5/100
60000/60000 [==============================] - 10s 170us/step - loss: 0.8822 - acc: 0.6739
Epoch 6/100
60000/60000 [==============================] - 10s 170us/step - loss: 0.8600 - acc: 0.6838
Epoch 7/100
60000/60000 [==============================] - 10s 170us/step - loss: 0.8426 - acc: 0.6908
Epoch 8/100
60000/60000 [==============================] - 10s 167us/step - loss: 0.8320 - acc: 0.6926
Epoch 9/100
60000/60000 [==============================] - 10s 168us/step - loss: 0.8210 - acc: 0.6989
Epoch 10/100
60000/60000 [==============================] - 10s 168us/step - loss: 0.8166 - acc: 0.7000
Epoch 11/100
60000/60000 [==============================] - 10s 168us/step - loss: 0.8017 - acc: 0.7043
Epoch 12/100
60000/60000 [==============================] - 10s 169us/step - loss: 0.8004 - acc: 0.7057
Epoch 13/100
60000/60000 [==============================] - 10s 169us/step - loss: 0.7877 - acc: 0.7097
Epoch 14/100
60000/60000 [==============================] - 10s 169us/step - loss: 0.7841 - acc: 0.7102
Epoch 15/100
60000/60000 [==============================] - 10s 169us/step - loss: 0.7807 - acc: 0.7135
Epoch 16/100
60000/60000 [==============================] - 10s 169us/step - loss: 0.7749 - acc: 0.7145
Epoch 17/100
60000/60000 [==============================] - 10s 169us/step - loss: 0.7703 - acc: 0.7143
Epoch 18/100
60000/60000 [==============================] - 10s 171us/step - loss: 0.7653 - acc: 0.7182
Epoch 19/100
60000/60000 [==============================] - 10s 168us/step - loss: 0.7627 - acc: 0.7200
Epoch 20/100
60000/60000 [==============================] - 10s 168us/step - loss: 0.7601 - acc: 0.7195
Epoch 21/100
60000/60000 [==============================] - 10s 168us/step - loss: 0.7545 - acc: 0.7217
Epoch 22/100
60000/60000 [==============================] - 10s 168us/step - loss: 0.7514 - acc: 0.7241
Epoch 23/100
60000/60000 [==============================] - 10s 168us/step - loss: 0.7481 - acc: 0.7262
Epoch 24/100
60000/60000 [==============================] - 10s 170us/step - loss: 0.7458 - acc: 0.7240
Epoch 25/100
60000/60000 [==============================] - 10s 170us/step - loss: 0.7430 - acc: 0.7253
Epoch 26/100
60000/60000 [==============================] - 10s 167us/step - loss: 0.7407 - acc: 0.7284
Epoch 27/100
60000/60000 [==============================] - 10s 167us/step - loss: 0.7355 - acc: 0.7298
```

```
Epoch 28/100
60000/60000 [==============================] - 10s 168us/step - loss: 0.7344 - acc: 0.7300
Epoch 29/100
60000/60000 [==============================] - 10s 168us/step - loss: 0.7318 - acc: 0.7302
Epoch 30/100
60000/60000 [==============================] - 10s 167us/step - loss: 0.7293 - acc: 0.7312
Epoch 31/100
60000/60000 [==============================] - 10s 167us/step - loss: 0.7271 - acc: 0.7325
Epoch 32/100
60000/60000 [==============================] - 10s 167us/step - loss: 0.7227 - acc: 0.7359
Epoch 33/100
60000/60000 [==============================] - 10s 166us/step - loss: 0.7200 - acc: 0.7348
Epoch 34/100
60000/60000 [==============================] - 10s 167us/step - loss: 0.7209 - acc: 0.7347
Epoch 35/100
60000/60000 [==============================] - 10s 167us/step - loss: 0.7186 - acc: 0.7353
Epoch 36/100
60000/60000 [==============================] - 10s 168us/step - loss: 0.7146 - acc: 0.7385
Epoch 37/100
60000/60000 [==============================] - 10s 168us/step - loss: 0.7126 - acc: 0.7381
Epoch 38/100
60000/60000 [==============================] - 10s 166us/step - loss: 0.7128 - acc: 0.7396
Epoch 39/100
60000/60000 [==============================] - 10s 168us/step - loss: 0.7117 - acc: 0.7376
Epoch 40/100
60000/60000 [==============================] - 10s 168us/step - loss: 0.7093 - acc: 0.7392
Epoch 41/100
60000/60000 [==============================] - 10s 169us/step - loss: 0.7078 - acc: 0.7404
Epoch 42/100
60000/60000 [==============================] - 10s 169us/step - loss: 0.7024 - acc: 0.7417
Epoch 43/100
60000/60000 [==============================] - 10s 168us/step - loss: 0.7051 - acc: 0.7413
Epoch 44/100
60000/60000 [==============================] - 10s 168us/step - loss: 0.7011 - acc: 0.7436
Epoch 45/100
60000/60000 [==============================] - 10s 168us/step - loss: 0.7043 - acc: 0.7423
Epoch 46/100
60000/60000 [==============================] - 10s 168us/step - loss: 0.6987 - acc: 0.7450
Epoch 47/100
60000/60000 [==============================] - 10s 169us/step - loss: 0.7011 - acc: 0.7422
Epoch 48/100
60000/60000 [==============================] - 10s 170us/step - loss: 0.6990 - acc: 0.7438
Epoch 49/100
60000/60000 [==============================] - 10s 168us/step - loss: 0.6958 - acc: 0.7435
Epoch 50/100
60000/60000 [==============================] - 10s 166us/step - loss: 0.6904 - acc: 0.7460
Epoch 51/100
60000/60000 [==============================] - 10s 168us/step - loss: 0.6954 - acc: 0.7459
Epoch 52/100
60000/60000 [==============================] - 10s 167us/step - loss: 0.6905 - acc: 0.7449
Epoch 53/100
60000/60000 [==============================] - 10s 167us/step - loss: 0.6918 - acc: 0.7483
Epoch 54/100
60000/60000 [==============================] - 10s 167us/step - loss: 0.6901 - acc: 0.7480
```

```
Epoch 55/100
60000/60000 [==============================] - 10s 169us/step - loss: 0.6887 - acc: 0.7466
Epoch 56/100
60000/60000 [==============================] - 10s 168us/step - loss: 0.6907 - acc: 0.7480
Epoch 57/100
60000/60000 [==============================] - 10s 166us/step - loss: 0.6871 - acc: 0.7490
Epoch 58/100
60000/60000 [==============================] - 10s 166us/step - loss: 0.6862 - acc: 0.7495
Epoch 59/100
60000/60000 [==============================] - 10s 167us/step - loss: 0.6871 - acc: 0.7489
Epoch 60/100
60000/60000 [==============================] - 10s 166us/step - loss: 0.6826 - acc: 0.7498
Epoch 61/100
60000/60000 [==============================] - 10s 167us/step - loss: 0.6808 - acc: 0.7499
Epoch 62/100
60000/60000 [==============================] - 10s 167us/step - loss: 0.6823 - acc: 0.7493
Epoch 63/100
60000/60000 [==============================] - 10s 166us/step - loss: 0.6785 - acc: 0.7519
Epoch 64/100
60000/60000 [==============================] - 10s 168us/step - loss: 0.6811 - acc: 0.7504
Epoch 65/100
60000/60000 [==============================] - 10s 168us/step - loss: 0.6795 - acc: 0.7510
Epoch 66/100
60000/60000 [==============================] - 10s 168us/step - loss: 0.6781 - acc: 0.7517
Epoch 67/100
60000/60000 [==============================] - 10s 168us/step - loss: 0.6784 - acc: 0.7516
Epoch 68/100
60000/60000 [==============================] - 10s 168us/step - loss: 0.6775 - acc: 0.7521
Epoch 69/100
60000/60000 [==============================] - 10s 168us/step - loss: 0.6746 - acc: 0.7526
Epoch 70/100
60000/60000 [==============================] - 10s 170us/step - loss: 0.6742 - acc: 0.7521
Epoch 71/100
60000/60000 [==============================] - 10s 170us/step - loss: 0.6751 - acc: 0.7525
Epoch 72/100
60000/60000 [==============================] - 10s 168us/step - loss: 0.6730 - acc: 0.7543
Epoch 73/100
60000/60000 [==============================] - 10s 168us/step - loss: 0.6699 - acc: 0.7551
Epoch 74/100
60000/60000 [==============================] - 10s 168us/step - loss: 0.6711 - acc: 0.7540
Epoch 75/100
60000/60000 [==============================] - 10s 168us/step - loss: 0.6671 - acc: 0.7561
Epoch 76/100
60000/60000 [==============================] - 10s 168us/step - loss: 0.6714 - acc: 0.7548
Epoch 77/100
60000/60000 [==============================] - 10s 168us/step - loss: 0.6685 - acc: 0.7548
Epoch 78/100
60000/60000 [==============================] - 10s 168us/step - loss: 0.6693 - acc: 0.7537
Epoch 79/100
60000/60000 [==============================] - 10s 168us/step - loss: 0.6654 - acc: 0.7574
Epoch 80/100
60000/60000 [==============================] - 10s 166us/step - loss: 0.6651 - acc: 0.7562
Epoch 81/100
60000/60000 [==============================] - 10s 167us/step - loss: 0.6710 - acc: 0.7552
```

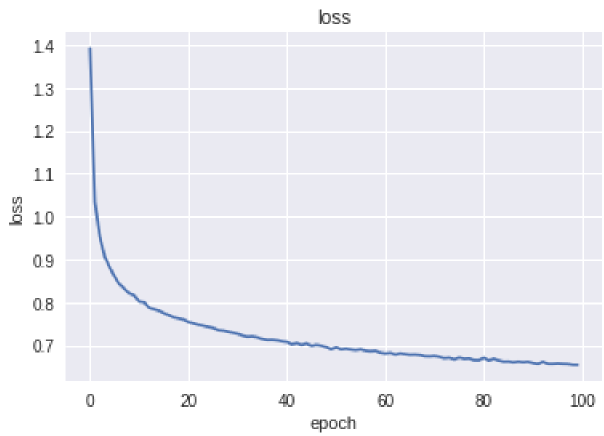
```
Epoch 82/100
60000/60000 [==============================] - 10s 167us/step - loss: 0.6645 - acc: 0.7581
Epoch 83/100
60000/60000 [==============================] - 10s 166us/step - loss: 0.6687 - acc: 0.7563
Epoch 84/100
60000/60000 [==============================] - 10s 168us/step - loss: 0.6646 - acc: 0.7566
Epoch 85/100
60000/60000 [==============================] - 10s 167us/step - loss: 0.6618 - acc: 0.7585
Epoch 86/100
60000/60000 [==============================] - 10s 169us/step - loss: 0.6622 - acc: 0.7571
Epoch 87/100
60000/60000 [==============================] - 10s 169us/step - loss: 0.6604 - acc: 0.7588
Epoch 88/100
60000/60000 [==============================] - 10s 167us/step - loss: 0.6620 - acc: 0.7579
Epoch 89/100
60000/60000 [==============================] - 10s 166us/step - loss: 0.6607 - acc: 0.7587
Epoch 90/100
60000/60000 [==============================] - 10s 166us/step - loss: 0.6617 - acc: 0.7585
Epoch 91/100
60000/60000 [==============================] - 10s 166us/step - loss: 0.6585 - acc: 0.7585
Epoch 92/100
60000/60000 [==============================] - 10s 168us/step - loss: 0.6565 - acc: 0.7614
Epoch 93/100
60000/60000 [==============================] - 10s 169us/step - loss: 0.6619 - acc: 0.7578
Epoch 94/100
60000/60000 [==============================] - 10s 168us/step - loss: 0.6567 - acc: 0.7607
Epoch 95/100
60000/60000 [==============================] - 10s 169us/step - loss: 0.6566 - acc: 0.7594
Epoch 96/100
60000/60000 [==============================] - 10s 170us/step - loss: 0.6575 - acc: 0.7604
Epoch 97/100
60000/60000 [==============================] - 10s 169us/step - loss: 0.6566 - acc: 0.7606
Epoch 98/100
60000/60000 [==============================] - 10s 169us/step - loss: 0.6564 - acc: 0.7596
Epoch 99/100
60000/60000 [==============================] - 10s 168us/step - loss: 0.6544 - acc: 0.7604
Epoch 100/100
60000/60000 [==============================] - 10s 168us/step - loss: 0.6542 - acc: 0.7620
```

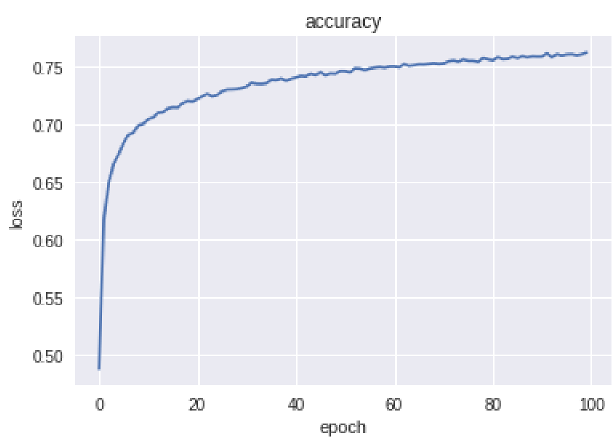
In [13]:
```
# Evaluate the model
score = trans_model.evaluate(test_features_flat, y_test, verbose=0)
print('Test Loss and Accuracy:', score)
```

```
Test Loss and Accuracy: [0.6929168213844299, 0.7504]
```

In [16]:
```
#Evaluate

plt.plot(transfer_model.history['loss'])
plt.ylabel('loss')
plt.xlabel('epoch')
plt.title('loss')
plt.show()
plt.plot(transfer_model.history['acc'])
plt.ylabel('loss')
plt.xlabel('epoch')
plt.title('accuracy')
plt.show()
```





3 Text classification

3.1 RNN

Build and train a Recurrent Neural Network to solve this text classification task. You can use any type of RNN you wish (SimpleRNN, GRU, LSTM).

In [2]:
```
%matplotlib inline

import numpy as np
import tensorflow as tf
import pandas as pd
import matplotlib.pyplot as plt
import skimage
import itertools

from string import printable
from keras import backend as K
from skimage.transform import resize
from keras.datasets import fashion_mnist
from keras import regularizers
from keras import callbacks
from keras.models import Sequential, Model
from keras.layers import Embedding, LSTM, Dense, Dropout, Activation, Flatten, Input, Conv2D, MaxPooling2D, UpSampling2D
from keras.layers import BatchNormalization, Lambda, Convolution1D, Convolution2D, ELU, concatenate
from keras.utils import np_utils
from keras.applications.vgg16 import VGG16, preprocess_input, decode_predictions
from keras.preprocessing import image
from keras.preprocessing.image import img_to_array, array_to_img
from keras.preprocessing.text import Tokenizer
from keras.preprocessing.sequence import pad_sequences
from sklearn.model_selection import train_test_split
from sklearn.feature_extraction.text import CountVectorizer
from sklearn.metrics import roc_curve, auc
from keras.optimizers import SGD, Adam, RMSprop
from keras.layers.advanced_activations import LeakyReLU
from keras.callbacks import EarlyStopping
```

```
Using TensorFlow backend.
```

In [7]:
```
import urllib3  # the lib that handles the url stuff
http = urllib3.PoolManager()
r_benign = http.request('GET', 'https://s3.amazonaws.com/anly-590/url-classification/benign-urls.txt')
beni=r_benign.data.decode('utf-8').splitlines()
beni=[w for w in beni if "#" not in w]

r_mali = http.request('GET', 'https://s3.amazonaws.com/anly-590/url-classification/malicious-urls.txt')
mali=r_mali.data.decode('utf-8').splitlines()
mali=[w for w in mali if "#" not in w]
```

```
/usr/local/lib/python3.6/dist-packages/urllib3/connectionpool.py:858: InsecureRequestWarning: Unverified HTTPS request is being m
ade. Adding certificate verification is strongly advised. See: https://urllib3.readthedocs.io/en/latest/advanced-usage.html#ssl-w
arnings
  InsecureRequestWarning)
/usr/local/lib/python3.6/dist-packages/urllib3/connectionpool.py:858: InsecureRequestWarning: Unverified HTTPS request is being m
ade. Adding certificate verification is strongly advised. See: https://urllib3.readthedocs.io/en/latest/advanced-usage.html#ssl-w
arnings
  InsecureRequestWarning)
```

In [0]:
```
import numpy as np
import pandas as pd
from string import printable
from keras.preprocessing.sequence import pad_sequences
from sklearn.model_selection import train_test_split

x_train = beni + mali
y_train = np.concatenate( [ np.ones(len(beni)), np.zeros(len(mali)) ])
df = pd.DataFrame({'urls':x_train, 'label':y_train})

# considering Python's 100 printable characters only and convert them to int
url_int_tokens = [[printable.index(x) + 1 for x in url if x in printable] for url in df.urls]

#  All URLs have to be of the same length. This results in cropping or padding with zeros. I choose a max length of 75 characters.
max_len=75
X = pad_sequences(url_int_tokens, maxlen=max_len)

# convert labels form df to numpy array
target = np.array(df.label)
X_train, X_test, target_train, target_test = train_test_split(X, target, test_size=0.25, random_state=33)
```

In [10]:
```
from keras import regularizers
from keras.layers import Embedding, LSTM, Dense, Dropout, Activation, Flatten, Input, Conv2D
from keras.models import Sequential, Model
from keras.optimizers import SGD, Adam, RMSprop
# LSTM Model

main_input = Input(shape=(75,), dtype='int32', name='main_input')
# Embedding layer
emb = Embedding(input_dim=100, output_dim=32, input_length=75,
            dropout=0.2, W_regularizer=regularizers.l2(1e-4))(main_input)

# LSTM layer
lstm = LSTM(32)(emb)
lstm = Dropout(0.5)(lstm)

# Output layer (last fully connected layer)
output = Dense(1, activation='sigmoid', name='output')(lstm)

# Compile model and define optimizer
model = Model(input=[main_input], output=[output])
adam = Adam(lr=1e-4, beta_1=0.9, beta_2=0.999, epsilon=1e-08, decay=0.0)
model.compile(optimizer=adam, loss='binary_crossentropy', metrics=['accuracy'])
model.summary()
```

```
/usr/local/lib/python3.6/dist-packages/ipykernel_launcher.py:10: UserWarning: The `dropout` argument is no longer support in `Emb
edding`. You can apply a `keras.layers.SpatialDropout1D` layer right after the `Embedding` layer to get the same behavior.
  # Remove the CWD from sys.path while we load stuff.
/usr/local/lib/python3.6/dist-packages/ipykernel_launcher.py:10: UserWarning: Update your `Embedding` call to the Keras 2 API: `E
mbedding(input_dim=100, output_dim=32, input_length=75, embeddings_regularizer=<keras.reg...)`
  # Remove the CWD from sys.path while we load stuff.

_________________________________________________________________
Layer (type)                 Output Shape              Param #   
=================================================================
main_input (InputLayer)      (None, 75)                0         
_________________________________________________________________
embedding_2 (Embedding)      (None, 75, 32)            3200      
_________________________________________________________________
lstm_1 (LSTM)                (None, 32)                8320      
_________________________________________________________________
dropout_8 (Dropout)          (None, 32)                0         
_________________________________________________________________
output (Dense)               (None, 1)                 33        
=================================================================
Total params: 11,553
Trainable params: 11,553
Non-trainable params: 0
_________________________________________________________________

/usr/local/lib/python3.6/dist-packages/ipykernel_launcher.py:20: UserWarning: Update your `Model` call to the Keras 2 API: `Model
(inputs=[<tf.Tenso..., outputs=[<tf.Tenso...)`
```

In [26]:
```
from keras.callbacks import EarlyStopping
eary_stopping = EarlyStopping(
    monitor='loss',
    min_delta=0,
    patience=10,
    verbose=1,
    mode='auto')


model.fit(X_train, target_train, epochs=10, batch_size=32, callbacks=[eary_stopping])
```

```
Epoch 1/10
50483/50483 [==============================] - 85s 2ms/step - loss: 0.0191 - acc: 0.9916
Epoch 2/10
50483/50483 [==============================] - 84s 2ms/step - loss: 0.0194 - acc: 0.9917
Epoch 3/10
50483/50483 [==============================] - 83s 2ms/step - loss: 0.0194 - acc: 0.9912
Epoch 4/10
50483/50483 [==============================] - 83s 2ms/step - loss: 0.0192 - acc: 0.9911
Epoch 5/10
50483/50483 [==============================] - 84s 2ms/step - loss: 0.0194 - acc: 0.9912
Epoch 6/10
50483/50483 [==============================] - 84s 2ms/step - loss: 0.0193 - acc: 0.9915
Epoch 7/10
50483/50483 [==============================] - 84s 2ms/step - loss: 0.0192 - acc: 0.9914
Epoch 8/10
50483/50483 [==============================] - 84s 2ms/step - loss: 0.0188 - acc: 0.9915
Epoch 9/10
50483/50483 [==============================] - 84s 2ms/step - loss: 0.0190 - acc: 0.9914
Epoch 10/10
50483/50483 [==============================] - 84s 2ms/step - loss: 0.0188 - acc: 0.9917
```

Out[26]:
```
<keras.callbacks.History at 0x7f517ece7ef0>
```

In [27]:
```
loss, accuracy = model.evaluate(X_test, target_test, verbose=1)
print('Accuracy: ', accuracy, '\n')
```

```
16828/16828 [==============================] - 5s 306us/step
Accuracy:  0.98924411690544
```

3.2 CNN

Build and train a 1D CNN for this text classification task. You might gain some insight and inspiration from these text classification approaches: • http://www.aclweb.org/anthology/D14-1181 (http://www.aclweb.org/anthology/D14-1181) • https://arxiv.org/abs/1702.08568 (https://arxiv.org/abs/1702.08568)

In [28]:
```
# CNN Model

max_len=75
emb_dim=32
max_vocab_len=100
W_reg=regularizers.l2(1e-4)

# Input
main_input = Input(shape=(max_len,), dtype='int32', name='main_input')
# Embedding layer
emb = Embedding(input_dim=max_vocab_len, output_dim=emb_dim, input_length=max_len,
            W_regularizer=W_reg)(main_input)
emb = Dropout(0.25)(emb)
```

```
/usr/local/lib/python3.6/dist-packages/ipykernel_launcher.py:11: UserWarning: Update your `Embedding` call to the Keras 2 API: `E
mbedding(input_dim=100, output_dim=32, input_length=75, embeddings_regularizer=<keras.reg...)`
  # This is added back by InteractiveShellApp.init_path()
```

In [29]:
```
def sum_1d(X):
    return K.sum(X, axis=1)

def get_conv_layer(emb, kernel_size=5, filters=256):
    # Conv layer
    conv = Convolution1D(kernel_size=kernel_size, filters=filters, \
                 border_mode='same')(emb)
    conv = ELU()(conv)

    conv = Lambda(sum_1d, output_shape=(filters,))(conv)
    #conv = BatchNormalization(mode=0)(conv)
    conv = Dropout(0.5)(conv)
    return conv

# Multiple Conv Layers

# calling custom conv function from above
conv1 = get_conv_layer(emb, kernel_size=2, filters=256)
conv2 = get_conv_layer(emb, kernel_size=3, filters=256)
conv3 = get_conv_layer(emb, kernel_size=4, filters=256)
conv4 = get_conv_layer(emb, kernel_size=5, filters=256)
```

```
/usr/local/lib/python3.6/dist-packages/ipykernel_launcher.py:6: UserWarning: Update your `Conv1D` call to the Keras 2 API: `Conv1
D(kernel_size=2, filters=256, padding="same")`

/usr/local/lib/python3.6/dist-packages/ipykernel_launcher.py:6: UserWarning: Update your `Conv1D` call to the Keras 2 API: `Conv1
D(kernel_size=3, filters=256, padding="same")`

/usr/local/lib/python3.6/dist-packages/ipykernel_launcher.py:6: UserWarning: Update your `Conv1D` call to the Keras 2 API: `Conv1
D(kernel_size=4, filters=256, padding="same")`

/usr/local/lib/python3.6/dist-packages/ipykernel_launcher.py:6: UserWarning: Update your `Conv1D` call to the Keras 2 API: `Conv1
D(kernel_size=5, filters=256, padding="same")`
```

In [30]:
```
# Fully Connected Layers
merged = concatenate([conv1,conv2,conv3,conv4], axis=1)

hidden1 = Dense(1024)(merged)
hidden1 = ELU()(hidden1)
hidden1 = BatchNormalization(mode=0)(hidden1)
hidden1 = Dropout(0.5)(hidden1)

hidden2 = Dense(1024)(hidden1)
hidden2 = ELU()(hidden2)
hidden2 = BatchNormalization(mode=0)(hidden2)
hidden2 = Dropout(0.5)(hidden2)

# Output layer (last fully connected layer)
output = Dense(1, activation='sigmoid', name='output')(hidden2)

# Compile model and define optimizer
cnn_model = Model(input=[main_input], output=[output])
adam = Adam(lr=1e-4, beta_1=0.9, beta_2=0.999, epsilon=1e-08, decay=0.0)
cnn_model.compile(optimizer=adam, loss='binary_crossentropy', metrics=['accuracy'])
cnn_model.summary()
```

```
/usr/local/lib/python3.6/dist-packages/ipykernel_launcher.py:5: UserWarning: Update your `BatchNormalization` call to the Keras 2
API: `BatchNormalization()`
  """
/usr/local/lib/python3.6/dist-packages/ipykernel_launcher.py:10: UserWarning: Update your `BatchNormalization` call to the Keras
2 API: `BatchNormalization()`
  # Remove the CWD from sys.path while we load stuff.
```

```
__________________________________________________________________________________________________
Layer (type)                    Output Shape         Param #     Connected to
==================================================================================================
main_input (InputLayer)         (None, 75)           0
__________________________________________________________________________________________________
embedding_6 (Embedding)         (None, 75, 32)       3200        main_input[0][0]
__________________________________________________________________________________________________
dropout_12 (Dropout)            (None, 75, 32)       0           embedding_6[0][0]
__________________________________________________________________________________________________
conv1d_5 (Conv1D)               (None, 75, 256)      16640       dropout_12[0][0]
__________________________________________________________________________________________________
conv1d_6 (Conv1D)               (None, 75, 256)      24832       dropout_12[0][0]
__________________________________________________________________________________________________
conv1d_7 (Conv1D)               (None, 75, 256)      33024       dropout_12[0][0]
__________________________________________________________________________________________________
conv1d_8 (Conv1D)               (None, 75, 256)      41216       dropout_12[0][0]
__________________________________________________________________________________________________
elu_7 (ELU)                     (None, 75, 256)      0           conv1d_5[0][0]
__________________________________________________________________________________________________
elu_8 (ELU)                     (None, 75, 256)      0           conv1d_6[0][0]
__________________________________________________________________________________________________
elu_9 (ELU)                     (None, 75, 256)      0           conv1d_7[0][0]
__________________________________________________________________________________________________
elu_10 (ELU)                    (None, 75, 256)      0           conv1d_8[0][0]
__________________________________________________________________________________________________
lambda_5 (Lambda)               (None, 256)          0           elu_7[0][0]
__________________________________________________________________________________________________
lambda_6 (Lambda)               (None, 256)          0           elu_8[0][0]
__________________________________________________________________________________________________
lambda_7 (Lambda)               (None, 256)          0           elu_9[0][0]
__________________________________________________________________________________________________
lambda_8 (Lambda)               (None, 256)          0           elu_10[0][0]
__________________________________________________________________________________________________
dropout_13 (Dropout)            (None, 256)          0           lambda_5[0][0]
__________________________________________________________________________________________________
dropout_14 (Dropout)            (None, 256)          0           lambda_6[0][0]
__________________________________________________________________________________________________
dropout_15 (Dropout)            (None, 256)          0           lambda_7[0][0]
__________________________________________________________________________________________________
dropout_16 (Dropout)            (None, 256)          0           lambda_8[0][0]
__________________________________________________________________________________________________
concatenate_2 (Concatenate)     (None, 1024)         0           dropout_13[0][0]
                                                                 dropout_14[0][0]
                                                                 dropout_15[0][0]
                                                                 dropout_16[0][0]
__________________________________________________________________________________________________
dense_3 (Dense)                 (None, 1024)         1049600     concatenate_2[0][0]
__________________________________________________________________________________________________
elu_11 (ELU)                    (None, 1024)         0           dense_3[0][0]
__________________________________________________________________________________________________
batch_normalization_3 (BatchNor (None, 1024)         4096        elu_11[0][0]
__________________________________________________________________________________________________
dropout_17 (Dropout)            (None, 1024)         0           batch_normalization_3[0][0]
__________________________________________________________________________________________________
```

```
dense_4 (Dense)              (None, 1024)         1049600     dropout_17[0][0]
____________________________________________________________________________________________________
elu_12 (ELU)                 (None, 1024)         0           dense_4[0][0]
____________________________________________________________________________________________________
batch_normalization_4 (BatchNor (None, 1024)      4096        elu_12[0][0]
____________________________________________________________________________________________________
dropout_18 (Dropout)         (None, 1024)         0           batch_normalization_4[0][0]
____________________________________________________________________________________________________
output (Dense)               (None, 1)            1025        dropout_18[0][0]
====================================================================================================
Total params: 2,227,329
Trainable params: 2,223,233
Non-trainable params: 4,096
____________________________________________________________________________________________________
```

```
/usr/local/lib/python3.6/dist-packages/ipykernel_launcher.py:17: UserWarning: Update your `Model` call to the Keras 2 API: `Model
(inputs=[<tf.Tenso..., outputs=[<tf.Tenso...)`
```

In [31]:

```
epochs = 10
batch_size = 25

eary_stopping = EarlyStopping(
    monitor='loss',
    min_delta=0,
    patience=10,
    verbose=1,
    mode='auto')

cnn_model.fit(X_train, target_train, epochs=epochs, batch_size=batch_size, callbacks=[eary_stopping])
```

```
Epoch 1/10
50483/50483 [==============================] - 196s 4ms/step - loss: 0.3013 - acc: 0.8796
Epoch 2/10
50483/50483 [==============================] - 194s 4ms/step - loss: 0.1158 - acc: 0.9747
Epoch 3/10
50483/50483 [==============================] - 193s 4ms/step - loss: 0.1030 - acc: 0.9761
Epoch 4/10
50483/50483 [==============================] - 194s 4ms/step - loss: 0.0914 - acc: 0.9771
Epoch 5/10
50483/50483 [==============================] - 193s 4ms/step - loss: 0.0780 - acc: 0.9773
Epoch 6/10
50483/50483 [==============================] - 194s 4ms/step - loss: 0.0724 - acc: 0.9782
Epoch 7/10
50483/50483 [==============================] - 194s 4ms/step - loss: 0.0624 - acc: 0.9797
Epoch 8/10
50483/50483 [==============================] - 195s 4ms/step - loss: 0.0584 - acc: 0.9806
Epoch 9/10
50483/50483 [==============================] - 195s 4ms/step - loss: 0.0520 - acc: 0.9813
Epoch 10/10
50483/50483 [==============================] - 195s 4ms/step - loss: 0.0447 - acc: 0.9828
```

Out[31]: <keras.callbacks.History at 0x7f517df3df60>

In [32]:
```
loss, accuracy = cnn_model.evaluate(X_test, target_test, verbose=1)
print('Accuracy:', accuracy, '\n')
```

```
16828/16828 [==============================] - 16s 938us/step
Accuracy: 0.9834799144283337
```

3.3

Be sure to directly compare your two methods with an ROC curve or similar validation method. Don’t forget to create a train-test split.

In [33]:
```
# LSTM and CNN ROC Curve
y_pred_keras = model.predict(X_test).ravel()
fpr_keras, tpr_keras, thresholds_keras = roc_curve(target_test, y_pred_keras)
auc_keras = auc(fpr_keras, tpr_keras)

cnn_y_pred_keras = cnn_model.predict(X_test).ravel()
cnn_fpr_keras, cnn_tpr_keras, cnn_thresholds_keras = roc_curve(target_test, cnn_y_pred_keras)
cnn_auc_keras = auc(cnn_fpr_keras, cnn_tpr_keras)

plt.figure(1)
plt.plot([0, 1], [0, 1], 'k--')
plt.plot(fpr_keras, tpr_keras, label='LSTM (area = {:.3f})'.format(auc_keras))
plt.plot(cnn_fpr_keras, cnn_tpr_keras, label='CNN (area = {:.3f})'.format(cnn_auc_keras))
plt.xlabel('False positive rate')
plt.ylabel('True positive rate')
plt.title('ROC curve')
plt.legend(loc='best')
plt.show()
```