In [1]:

```
# load emnist samples and adjust data
```

In [2]:

```
import keras
import numpy as np
import matplotlib.pyplot as plt
%matplotlib inline
```

```
/anaconda3/lib/python3.6/site-packages/h5py/__init__.py:34: FutureWarn
ing: Conversion of the second argument of issubdtype from `float` to `
np.floating` is deprecated. In future, it will be treated as `np.float
64 == np.dtype(float).type`.
  from ._conv import register_converters as _register_converters
Using TensorFlow backend.
```

In [3]:

```
import scipy.io
def load_emnist(file_path='emnist-bymerge.mat'):
    """
    Loads training and test data with ntr and nts training and test samples
    The `file_path` is the location of the `eminst-balanced.mat`.
    """

    # Load the MATLAB file
    mat = scipy.io.loadmat(file_path)

    # Get the training data
    Xtr = mat['dataset'][0][0][0][0][0][0][:]
    ntr = Xtr.shape[0]
    ytr = mat['dataset'][0][0][0][0][0][1][:].reshape(ntr).astype(int)

    # Get the test data
    Xts = mat['dataset'][0][0][1][0][0][0][:]
    nts = Xts.shape[0]
    yts = mat['dataset'][0][0][1][0][0][1][:].reshape(nts).astype(int)

    print("%d training samples, %d test samples loaded" % (ntr, nts))

    return [Xtr, Xts, ytr, yts]
```

In [4]:

```
Xtr, Xts, ytr, yts = load_emnist()
```

```
697932 training samples, 116323 test samples loaded
```

In [5]:

```
print(Xtr.shape,Xts.shape,ytr.shape,yts.shape)
```

```
(697932, 784) (116323, 784) (697932,) (116323,)
```

In [6]:

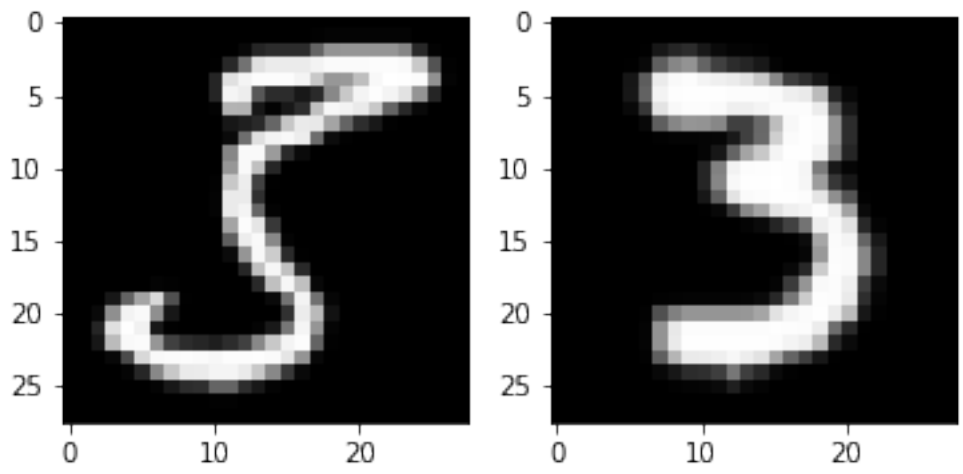
```
Xtrd=np.reshape(Xtr,(697932,28,28),order='F')
Xtsd=np.reshape(Xts,(116323,28,28),order='F')
```

In [7]:

```
plt.subplot(1,2,1)
plt.imshow(Xtrd[np.random.randint(1,20000),:,:],cmap='Greys_r')
plt.subplot(1,2,2)
plt.imshow(Xtsd[np.random.randint(1,10000),:,:],cmap='Greys_r')
```

Out[7]:

```
<matplotlib.image.AxesImage at 0x10e4982b0>
```




In [8]:

```
ntr = 46000
nts = 10000

# TODO: proper decide the number of samples and the ratio between dig and let

# Create sub-sampled training and test data
nsamp = Xtr.shape[0]
Iperm = np.random.permutation(nsamp)
Xtr1 = Xtrd[Iperm[:ntr],:,:]
ytr1 = ytr[Iperm[:ntr]]
nsamp = Xts.shape[0]
Iperm = np.random.permutation(nsamp)
Xts1 = Xtsd[Iperm[:nts],:,:]
yts1 = yts[Iperm[:nts]]
```

In [9]:

```
print(Xtr1.shape)
print(Xtr1[233,15:20,15:20])
print(ytr1)
```

```
(46000, 28, 28)
[[37  0  0  0  0]
 [37  0  0  0  0]
 [37  0  0  0  0]
 [21  0  0  0  0]
 [ 4  0  0  0  0]]
[21  5  8 ...  2  8 29]
```

In [10]:

```
from __future__ import print_function
# from keras.datasets import cifar10
from keras.preprocessing.image import ImageDataGenerator
from keras.models import Sequential
from keras.models import load_model #save and load models
from keras.layers import Dense, Dropout, Activation, Flatten
from keras.layers import Conv2D, MaxPooling2D
from keras.layers.normalization import BatchNormalization
import keras.backend as K
```

In [11]:

```
x_train = Xtr1.astype('float32')
x_test = Xts1.astype('float32')
x_train /= 255
x_test /= 255
x_train=x_train.reshape((ntr,28,28,1))
x_test=x_test.reshape((nts,28,28,1))
y_train=ytr1.reshape((len(ytr1),1))
y_test=yts1.reshape((len(yts1),1))
print(x_train.shape,x_test.shape,y_train.shape,y_test.shape)
```

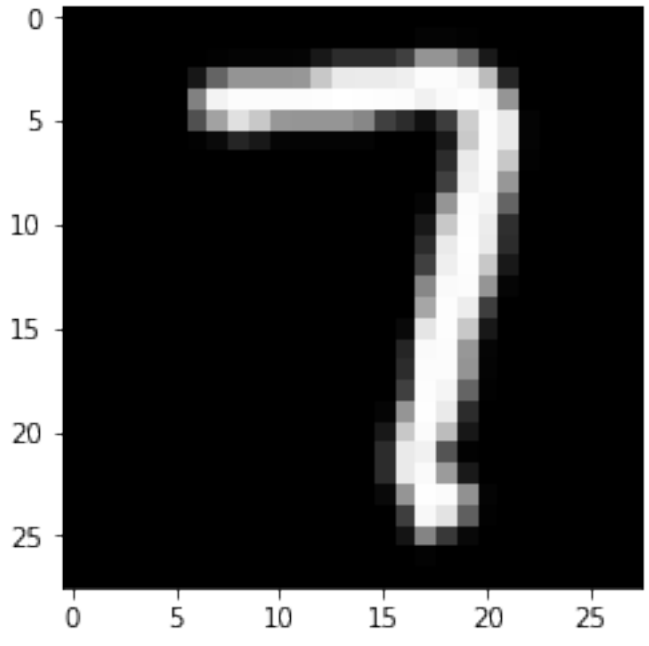
```
(46000, 28, 28, 1) (10000, 28, 28, 1) (46000, 1) (10000, 1)
```

In [12]:

```
myxt=np.zeros((28,28))
myxt[:,:]=x_test[np.random.randint(1,10000),:,:,0]
plt.imshow(myxt,cmap='Greys_r')
```

Out[12]:

```
<matplotlib.image.AxesImage at 0x18160f5c88>
```




In [13]:

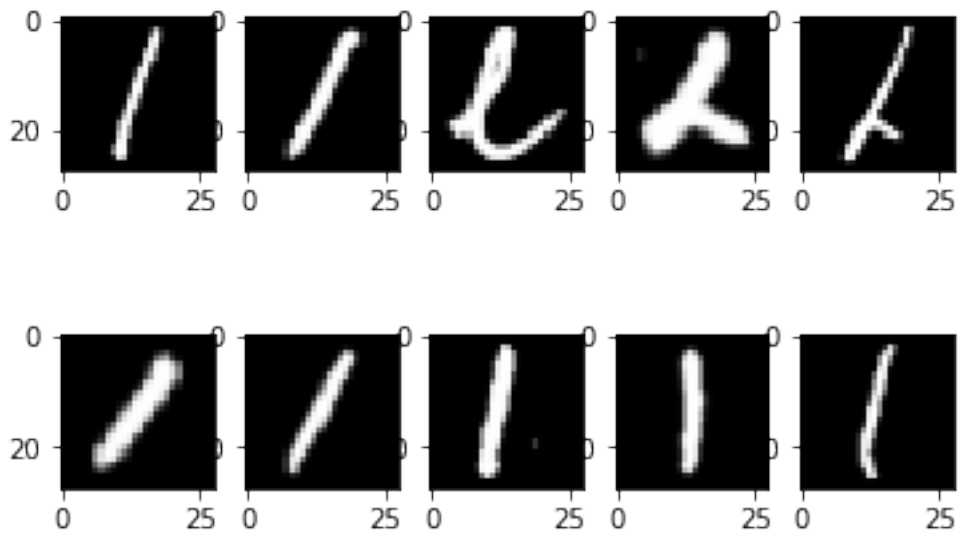
```
# remove the confusing data: F
'''
num=15
for m in range(len(y_train)):
    r=np.where(y_train==num)
    x_train[r,:,:,0]=0
for m in range(len(y_test)):
    r=np.where(y_test==num)
    x_test[r,:,:,0]=0
'''
```

Out[13]:

```
'\nnum=15\nfor m in range(len(y_train)):\n    r=np.where(y_train==num)
\n    x_train[r,:,:,0]=0\nfor m in range(len(y_test)):\n    r=np.where
(y_test==num)\n    x_test[r,:,:,0]=0\n'
```

In [14]:

```
# find the respective letter
num=21
for m in range(10):
    r=np.where(y_train==num)[0][m]
    myxt[:,:]=x_train[r,:,:,0]
    plt.subplot(2,5,m+1)
    plt.imshow(myxt,cmap='Greys_r')
```




In [15]:

```
num_classes = 47
y_train = keras.utils.to_categorical(y_train, num_classes)
y_test = keras.utils.to_categorical(y_test, num_classes)
print('Number of classes:', y_train.shape[1])
```

```
Number of classes: 47
```

In [16]:

```
batch_size = 64
epochs = 8
lrate = 0.05
decay = lrate/epochs
```

In [293]:

```
# TODO: 36/62 channels?
K.clear_session()
model = Sequential()
model.add(Conv2D(32, (3, 3),
                 padding='valid',
                 input_shape=x_train.shape[1:],
                 activation='relu'))
model.add(MaxPooling2D(pool_size=(2, 2)))
model.add(BatchNormalization())
model.add(Conv2D(32, (3, 3), padding='valid', activation='relu'))
model.add(MaxPooling2D(pool_size=(2, 2)))
model.add(Flatten())
model.add(BatchNormalization())
model.add(Dense(512, activation='relu'))
model.add(BatchNormalization())
model.add(Dense(num_classes, activation='softmax'))
```

In [294]:

```
# initiate Adam optimizer
opt = keras.optimizers.adam(lr=lrate, decay=decay)

# Let's train the model using Adam
model.compile(loss='categorical_crossentropy',
              optimizer=opt,
              metrics=['accuracy'])
print(model.summary())
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_1 (Conv2D)            (None, 26, 26, 32)        320
_________________________________________________________________
max_pooling2d_1 (MaxPooling2 (None, 13, 13, 32)        0
_________________________________________________________________
batch_normalization_1 (Batch (None, 13, 13, 32)        128
_________________________________________________________________
conv2d_2 (Conv2D)            (None, 11, 11, 32)        9248
_________________________________________________________________
max_pooling2d_2 (MaxPooling2 (None, 5, 5, 32)          0
_________________________________________________________________
flatten_1 (Flatten)          (None, 800)               0
_________________________________________________________________
batch_normalization_2 (Batch (None, 800)               3200
_________________________________________________________________
dense_1 (Dense)              (None, 512)               410112
_________________________________________________________________
batch_normalization_3 (Batch (None, 512)               2048
_________________________________________________________________
dense_2 (Dense)              (None, 47)                24111
=================================================================
Total params: 449,167
Trainable params: 446,479
Non-trainable params: 2,688
_________________________________________________________________
None
```

In [295]:

```
seed=7
k=1
c=4
# Fit the model
np.random.seed(seed)
class_weight={0:k*1.3,1:k/1.8,2:k/1.1,3:k,4:k,5:k*1.5,6:k,7:k,8:k*2,9:k*2,10:k,
              22:k,23:k,24:k*2,25:k,26:k,27:k,28:k,29:k,30:k,31:k,32:k,33:k,34:
              43:k,44:k*9,45:k,46:k}
hist_basic = model.fit(x_train, y_train,batch_size=batch_size,epochs=epochs,vali
                       #class_weight='auto'
                      )

print('Done!')
```

```
Train on 46000 samples, validate on 10000 samples
Epoch 1/8
46000/46000 [==============================] - 63s 1ms/step - loss: 0.
6302 - acc: 0.8027 - val_loss: 0.4271 - val_acc: 0.8616
Epoch 2/8
46000/46000 [==============================] - 63s 1ms/step - loss: 0.
3775 - acc: 0.8687 - val_loss: 0.4012 - val_acc: 0.8638
Epoch 3/8
46000/46000 [==============================] - 64s 1ms/step - loss: 0.
3123 - acc: 0.8860 - val_loss: 0.4087 - val_acc: 0.8629
Epoch 4/8
46000/46000 [==============================] - 63s 1ms/step - loss: 0.
2725 - acc: 0.8980 - val_loss: 0.3972 - val_acc: 0.8673
Epoch 5/8
46000/46000 [==============================] - 61s 1ms/step - loss: 0.
2424 - acc: 0.9065 - val_loss: 0.4307 - val_acc: 0.8664
Epoch 6/8
46000/46000 [==============================] - 63s 1ms/step - loss: 0.
2147 - acc: 0.9152 - val_loss: 0.4057 - val_acc: 0.8675
Epoch 7/8
46000/46000 [==============================] - 66s 1ms/step - loss: 0.
1971 - acc: 0.9217 - val_loss: 0.4199 - val_acc: 0.8656
Epoch 8/8
46000/46000 [==============================] - 62s 1ms/step - loss: 0.
1821 - acc: 0.9266 - val_loss: 0.4359 - val_acc: 0.8622
Done!
```

In [296]:

```
model.save("emnist_BatchNormalization_47_classwight_kernel2.h5")
model = load_model("emnist_BatchNormalization_47_classwight_kernel2.h5")
```

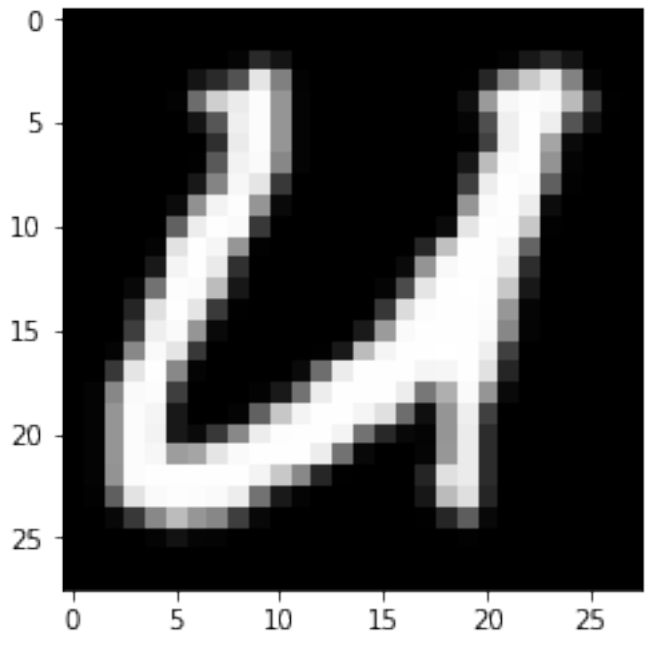
In [297]:

```
## prediction based on the model
```

In [298]:

```
myn=np.random.randint(1,20000)
myxtr=np.array(x_train[myn,:,:,:])
myxtrp=np.reshape(myxtr,(28,28))
plt.imshow(myxtrp,cmap='Greys_r')
myxtr=np.reshape(myxtr,(1,28,28,1))
preds = model.predict(myxtr)
print(preds)
print(np.argmax(preds))
print(y_train[myn])
if np.argmax(y_train[myn])<10:
    ascii=48+np.argmax(y_train[myn])
else:
    ascii=87+np.argmax(y_train[myn])
print(chr(ascii))
```

```
[[1.23515804e-07 3.72122955e-08 3.33188154e-07 5.02231833e-11
  2.66159816e-07 7.74245723e-10 2.93974267e-06 8.25428259e-09
  1.30503670e-08 1.94423663e-07 3.92194522e-07 9.07756856e-08
  1.39135006e-11 5.67333132e-08 9.90347626e-09 1.37257697e-12
  2.46301897e-06 1.12099215e-05 5.48474244e-09 7.67718422e-09
  4.68045869e-07 3.39324941e-08 7.82226408e-08 5.11993903e-07
  8.78020046e-10 9.56579260e-12 2.21214600e-06 4.08123579e-09
  1.49083142e-11 3.07458663e-08 9.69479024e-01 2.14808570e-05
  3.04293744e-02 2.45321161e-07 4.07663583e-06 3.00070724e-08
  8.79328638e-07 2.48769254e-08 9.38984249e-06 4.17549190e-10
  1.87652158e-10 1.93214706e-08 3.35925979e-05 6.83860790e-08
  2.19290456e-07 5.72550236e-11 3.96266930e-09]]
30
[0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.
0.
 0. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
u
```



In [299]:

```
yhat=model.predict(x_test)
yhatp=np.argmax(yhat,axis=1)
ytsp=np.argmax(y_test,axis=1)
acc = np.mean(yhatp == ytsp)
print('Accuaracy = {0:f}'.format(acc))
```

```
Accuaracy = 0.862200
```

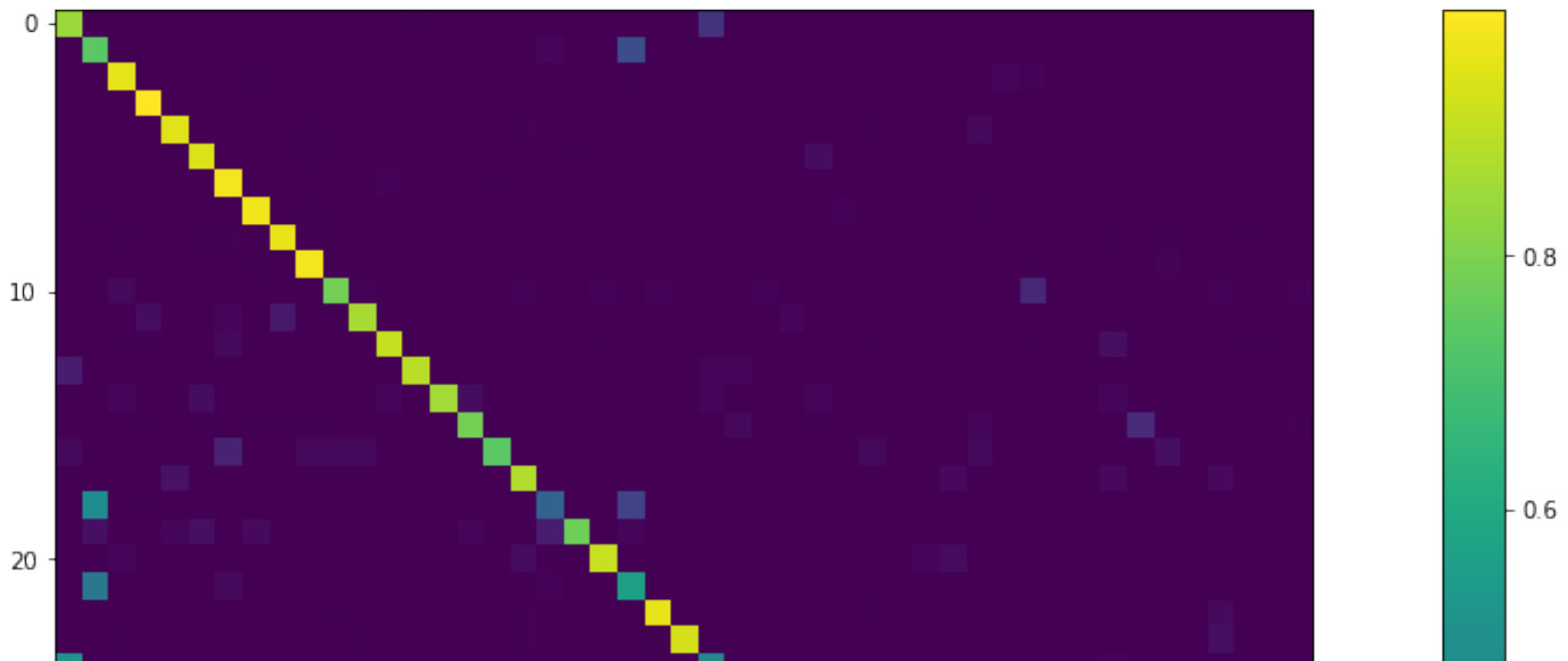
In [300]:

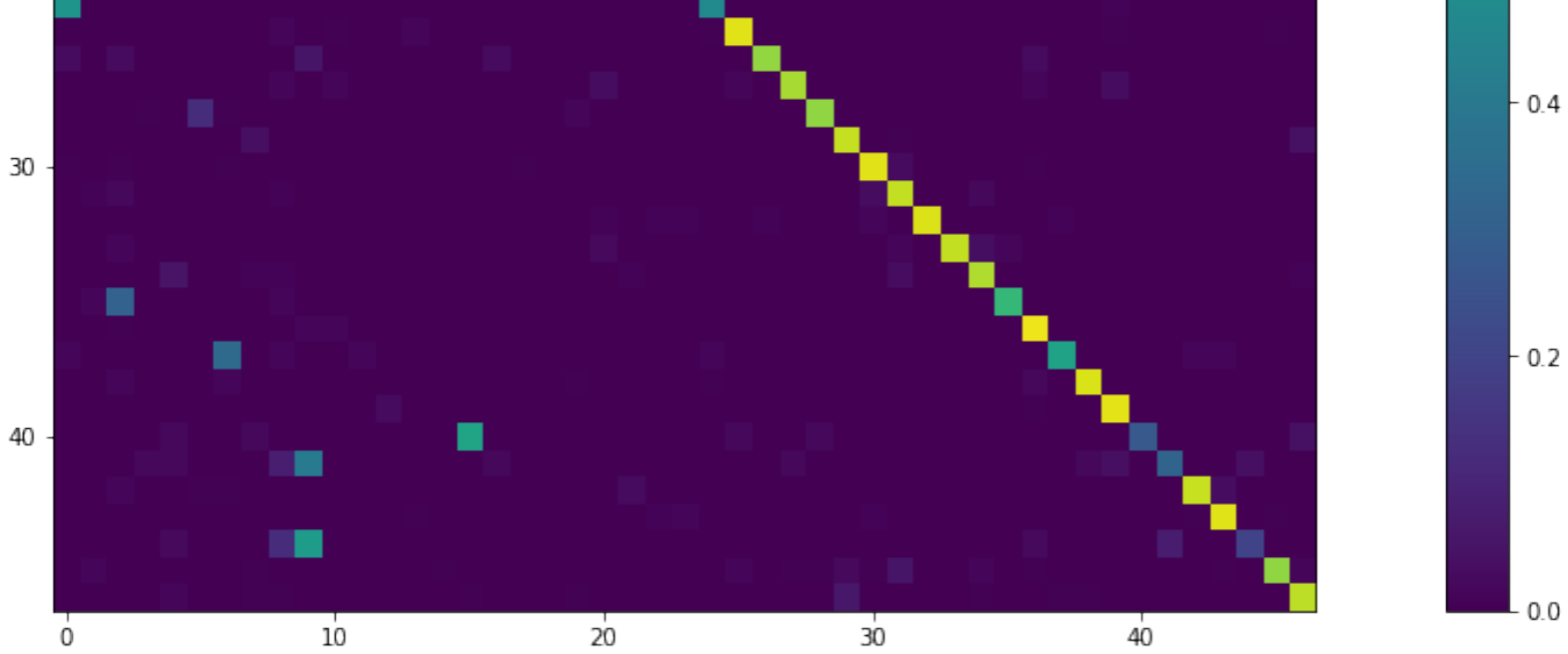
```
from sklearn.metrics import confusion_matrix
from sklearn.preprocessing import normalize

C = confusion_matrix(ytsp,yhatp)

# Normalize the confusion matrix
#Csum = np.sum(C,1)
#C = C / Csum[None,:]
C = normalize(C, norm='l1', axis=1)

# Print the confusion matrix
print(np.array_str(C, precision=3, suppress_small=True))
plt.figure(figsize=(20, 10))
plt.imshow(C, interpolation='none')
plt.colorbar()
```

```
[[0.843 0.    0.    ... 0.    0.    0.   ]
 [0.    0.739 0.002 ... 0.    0.    0.   ]
 [0.    0.    0.957 ... 0.    0.    0.   ]
 ...
 [0.    0.    0.    ... 0.2   0.    0.   ]
 [0.    0.014 0.    ... 0.    0.829 0.014]
 [0.    0.    0.    ... 0.    0.    0.895]]
```

Out[300]:

```
<matplotlib.colorbar.Colorbar at 0x18304090b8>
```






In [301]:

```
1 Cd=C.diagonal()
2 print(Cd)
3 print(np.where(Cd<0.8))
```

```
[0.84325397 0.73854962 0.95687885 0.99441341 0.94639175 0.94305239
 0.97797357 0.97194389 0.96082474 0.975      0.78409091 0.86440678
 0.90769231 0.89230769 0.85483871 0.78787879 0.74       0.87804878
 0.31279621 0.77333333 0.90909091 0.56610169 0.95679012 0.93023256
 0.47150259 0.95092025 0.83333333 0.86440678 0.82857143 0.90849673
 0.94977169 0.90322581 0.94117647 0.9047619  0.875      0.66233766
 0.96969697 0.57142857 0.93835616 0.95396419 0.27906977 0.31914894
 0.9109589  0.94565217 0.2        0.82938389 0.89495798]
(array([ 1, 10, 15, 16, 18, 19, 21, 24, 35, 37, 40, 41, 44]),)
```

In [ ]:

```
1 # use a loop to find the best parameter
```

In [303]:

```
 1 history=[]
 2 nodes=np.array([384,512,640])
 3 nconvs=np.array([16,32,48])
 4 for i,nc in enumerate(nconvs):
 5     for j,node in enumerate(nodes):
 6         K.clear_session()
 7         model = Sequential()
 8         model.add(Conv2D(nc, (3, 3),
 9                          padding='valid',
10                          input_shape=x_train.shape[1:],
11                          activation='relu'))
12         #model.add(BatchNormalization())
13         #model.add(Conv2D(32, (3, 3), padding='valid', activation='relu'))   #+(
14         model.add(MaxPooling2D(pool_size=(2, 2)))
15         model.add(BatchNormalization())
16         model.add(Conv2D(nc, (3, 3), padding='valid', activation='relu'))
```

```
        model.add(MaxPooling2D(pool_size=(2, 2)))
        #model.add(Conv2D(28, (3, 3), padding='valid', activation='relu'))   #+
        #model.add(BatchNormalization())

        model.add(Flatten())
        model.add(BatchNormalization())
        model.add(Dense(node, activation='relu'))
        model.add(BatchNormalization())
        #model.add(Dense(62, activation='relu'))   #+0.01
        #model.add(BatchNormalization())
        opt = keras.optimizers.adam(lr=lrate, decay=decay)
        model.add(Dense(num_classes, activation='softmax'))
        model.compile(loss='categorical_crossentropy',
              optimizer=opt,
              metrics=['accuracy'])
        print('nc={},node={}'.format(nc,node))
        hist_basic = model.fit(x_train, y_train,batch_size=batch_size,
                               epochs=epochs,validation_data=(x_test, y_test),sh
        history.append(hist_basic)

```

```
nc=16,node=384
Train on 46000 samples, validate on 10000 samples
Epoch 1/8
46000/46000 [==============================] - 29s 640us/step - loss:
0.7548 - acc: 0.7863 - val_loss: 0.4637 - val_acc: 0.8417
Epoch 2/8
46000/46000 [==============================] - 28s 614us/step - loss:
0.3944 - acc: 0.8632 - val_loss: 0.3924 - val_acc: 0.8644
Epoch 3/8
46000/46000 [==============================] - 28s 606us/step - loss:
0.3256 - acc: 0.8814 - val_loss: 0.3784 - val_acc: 0.8740
Epoch 4/8
46000/46000 [==============================] - 29s 625us/step - loss:
0.2899 - acc: 0.8925 - val_loss: 0.3865 - val_acc: 0.8741
Epoch 5/8
46000/46000 [==============================] - 28s 608us/step - loss:
0.2595 - acc: 0.9013 - val_loss: 0.3888 - val_acc: 0.8737
Epoch 6/8
46000/46000 [==============================] - 28s 611us/step - loss:
```

In [304]:

```
h=np.zeros((9,1))
for n in range(9):
    h[n]=np.max(history[n].history['val_acc'])
h1=h.reshape((len(nconvs),len(nodes)))
print(h1)
print(h1.shape)
c=0
for i,nc in enumerate(nconvs):
    for j,node in enumerate(nodes):
        if h1[i,j]>c:
            c=h1[i,j]
            convmax=nc
            nodemax=node
print('the best nconvs is {},the best nnode is {}'.format(convmax,nodemax))
print('the maximum val_accuracy is {}'.format(np.max(h1)))
```

```
[[0.8748 0.8751 0.8799]
 [0.8825 0.8765 0.8754]
 [0.8811 0.8799 0.8785]]
(3, 3)
the best nconvs is 32,the best nnode is 384
the maximum val_accuracy is 0.8825
```

In [ ]:

```
# go further from above to find better nconvs and n node
```

In [305]:

```
history=[]
nodes=np.array([320,384,448])
nconvs=np.array([24,32,40])
for i,nc in enumerate(nconvs):
    for j,node in enumerate(nodes):
        K.clear_session()
        model = Sequential()
        model.add(Conv2D(nc, (3, 3),
                         padding='valid',
                         input_shape=x_train.shape[1:],
                         activation='relu'))
        #model.add(BatchNormalization())
        #model.add(Conv2D(32, (3, 3), padding='valid', activation='relu'))   #+
        model.add(MaxPooling2D(pool_size=(2, 2)))
        model.add(BatchNormalization())
        model.add(Conv2D(nc, (3, 3), padding='valid', activation='relu'))
        model.add(MaxPooling2D(pool_size=(2, 2)))
        #model.add(Conv2D(28, (3, 3), padding='valid', activation='relu'))   #+
        #model.add(BatchNormalization())

        model.add(Flatten())
        model.add(BatchNormalization())
```

```
23          model.add(Dense(node, activation='relu'))
24          model.add(BatchNormalization())
25          #model.add(Dense(62, activation='relu'))   #+0.01
26          #model.add(BatchNormalization())
27          opt = keras.optimizers.adam(lr=lrate, decay=decay)
28          model.add(Dense(num_classes, activation='softmax'))
29          model.compile(loss='categorical_crossentropy',
30                optimizer=opt,
31                metrics=['accuracy'])
32          print('nc={},node={}'.format(nc,node))
33          hist_basic = model.fit(x_train, y_train,batch_size=batch_size,
34                                 epochs=epochs,validation_data=(x_test, y_test),sh
35          history.append(hist_basic)
36
```

```
nc=24,node=320
Train on 46000 samples, validate on 10000 samples
Epoch 1/8
46000/46000 [==============================] - 48s 1ms/step - loss: 0.
6819 - acc: 0.7966 - val_loss: 0.4265 - val_acc: 0.8564
Epoch 2/8
46000/46000 [==============================] - 45s 978us/step - loss:
0.3733 - acc: 0.8688 - val_loss: 0.3767 - val_acc: 0.8716
Epoch 3/8
46000/46000 [==============================] - 45s 981us/step - loss:
0.3129 - acc: 0.8860 - val_loss: 0.3692 - val_acc: 0.8732
Epoch 4/8
46000/46000 [==============================] - 46s 996us/step - loss:
0.2722 - acc: 0.8973 - val_loss: 0.3689 - val_acc: 0.8759
Epoch 5/8
46000/46000 [==============================] - 47s 1ms/step - loss: 0.
2435 - acc: 0.9066 - val_loss: 0.3786 - val_acc: 0.8713
Epoch 6/8
46000/46000 [==============================] - 47s 1ms/step - loss: 0.
2218 - acc: 0.9136 - val_loss: 0.3775 - val_acc: 0.8767
```

In [306]:

```
h=np.zeros((9,1))
for n in range(9):
    h[n]=np.max(history[n].history['val_acc'])
h1=h.reshape((len(nconvs),len(nodes)))
print(h1)
print(h1.shape)
c=0
for i,nc in enumerate(nconvs):
    for j,node in enumerate(nodes):
        if h1[i,j]>c:
            c=h1[i,j]
            convmax=nc
            nodemax=node
print('the best nconvs is {},the best nnode is {}'.format(convmax,nodemax))
print('the maximum val_accuracy is {}'.format(np.max(h1)))
```

```
[[0.8789 0.8795 0.8801]
 [0.8808 0.8794 0.879 ]
 [0.8789 0.8824 0.8777]]
(3, 3)
the best nconvs is 40,the best nnode is 384
the maximum val_accuracy is 0.8824
```

In [ ]:

```
# find the best parameters in adam optimizer
```

In [307]:

```
history1=[]
nlrate=np.array([0.5,0.1,0.05,0.01,0.005])
for i,lrate in enumerate(nlrate):
    K.clear_session()
    model = Sequential()
    model.add(Conv2D(convmax, (3, 3),
                     padding='valid',
                     input_shape=x_train.shape[1:],
                     activation='relu'))
    #model.add(BatchNormalization())
    #model.add(Conv2D(32, (3, 3), padding='valid', activation='relu'))   #+0.01
    model.add(MaxPooling2D(pool_size=(2, 2)))
    model.add(BatchNormalization())
    model.add(Conv2D(convmax, (3, 3), padding='valid', activation='relu'))
    model.add(MaxPooling2D(pool_size=(2, 2)))
    #model.add(Conv2D(28, (3, 3), padding='valid', activation='relu'))   #+0.00
    #model.add(BatchNormalization())

    model.add(Flatten())
    model.add(BatchNormalization())
    model.add(Dense(nodemax, activation='relu'))
    model.add(BatchNormalization())
```

```
    #model.add(Dense(62, activation='relu'))   #+0.01
    #model.add(BatchNormalization())
    decay = lrate/epochs
    opt = keras.optimizers.adam(lr=lrate, decay=decay)
    model.add(Dense(num_classes, activation='softmax'))
    model.compile(loss='categorical_crossentropy',optimizer=opt,metrics=['accura
    print('nlrate={}'.format(lrate))
    hist_basic = model.fit(x_train, y_train,batch_size=batch_size,epochs=epochs,
                           validation_data=(x_test, y_test),shuffle=True)
    history1.append(hist_basic)

```

```
nlrate=0.5
Train on 46000 samples, validate on 10000 samples
Epoch 1/8
46000/46000 [==============================] - 71s 2ms/step - loss: 15
.3239 - acc: 0.0481 - val_loss: 15.3364 - val_acc: 0.0485
Epoch 2/8
46000/46000 [==============================] - 70s 2ms/step - loss: 15
.3378 - acc: 0.0484 - val_loss: 15.3380 - val_acc: 0.0484
Epoch 3/8
46000/46000 [==============================] - 70s 2ms/step - loss: 15
.3378 - acc: 0.0484 - val_loss: 15.3364 - val_acc: 0.0485
Epoch 4/8
46000/46000 [==============================] - 69s 2ms/step - loss: 15
.3378 - acc: 0.0484 - val_loss: 15.3380 - val_acc: 0.0484
Epoch 5/8
46000/46000 [==============================] - 69s 2ms/step - loss: 15
.3378 - acc: 0.0484 - val_loss: 15.3373 - val_acc: 0.0484
Epoch 6/8
46000/46000 [==============================] - 73s 2ms/step - loss: 15
```

In [308]:

```
hh=np.zeros((5,1))
for n in range(5):
    hh[n]=np.max(history1[n].history['val_acc'])
print(hh)
c=0
for i,lrate in enumerate(nlrate):
    if hh[i]>c:
        c=hh[i]
        lratemax=lrate
print('the best nlrate is {}'.format(lratemax))
print('the maximum val_accuracy is {}'.format(np.max(hh)))
```

```
[[0.0485]
 [0.8681]
 [0.8778]
 [0.8789]
 [0.8832]]
the best nlrate is 0.005
the maximum val_accuracy is 0.8832
```

In [20]:

```
history=[]
nodes=np.array([512,640,768])
nconvs=np.array([16,32,48])
for i,nc in enumerate(nconvs):
    for j,node in enumerate(nodes):
        K.clear_session()
        model = Sequential()
        model.add(Conv2D(nc, (3, 3),
                         padding='valid',
                         input_shape=x_train.shape[1:],
                         activation='relu'))
        #model.add(BatchNormalization())
        #model.add(Conv2D(32, (3, 3), padding='valid', activation='relu'))   #+
        model.add(MaxPooling2D(pool_size=(2, 2)))
        model.add(Dropout(0.15))
        model.add(BatchNormalization())
        model.add(Conv2D(nc, (3, 3), padding='valid', activation='relu'))
        model.add(MaxPooling2D(pool_size=(2, 2)))
        #model.add(Conv2D(28, (3, 3), padding='valid', activation='relu'))   #+
        #model.add(BatchNormalization())
        model.add(Dropout(0.45))

        model.add(Flatten())
        model.add(BatchNormalization())
        model.add(Dense(node, activation='relu'))
        model.add(BatchNormalization())
        #model.add(Dense(62, activation='relu'))   #+0.01
        #model.add(BatchNormalization())
        model.add(Dropout(0.6))
        model.add(Dense(num_classes, activation='softmax'))
        decay = 0.005/epochs
        opt = keras.optimizers.adam(lr=0.005, decay=decay)
        model.compile(loss='categorical_crossentropy',
              optimizer=opt,
              metrics=['accuracy'])
        print('nc={},node={}'.format(nc,node))
        hist_basic = model.fit(x_train, y_train,batch_size=batch_size,
                               epochs=epochs,validation_data=(x_test, y_test),sh
        history.append(hist_basic)

```

```
nc=16,node=512
Train on 46000 samples, validate on 10000 samples
Epoch 1/8
46000/46000 [==============================] - 37s 796us/step - loss:
1.2729 - acc: 0.6410 - val_loss: 0.5674 - val_acc: 0.8055
Epoch 2/8
46000/46000 [==============================] - 36s 779us/step - loss:
0.7804 - acc: 0.7468 - val_loss: 0.4584 - val_acc: 0.8478
Epoch 3/8
46000/46000 [==============================] - 36s 773us/step - loss:
0.6805 - acc: 0.7771 - val_loss: 0.4319 - val_acc: 0.8491
```

```
Epoch 4/8
46000/46000 [==============================] - 36s 775us/step - loss:
0.6393 - acc: 0.7880 - val_loss: 0.4124 - val_acc: 0.8636
Epoch 5/8
46000/46000 [==============================] - 36s 779us/step - loss:
0.5937 - acc: 0.8018 - val_loss: 0.3883 - val_acc: 0.8653
Epoch 6/8
46000/46000 [==============================] - 37s 805us/step - loss:
```

In [21]:

```
h=np.zeros((9,1))
for n in range(9):
    h[n]=np.max(history[n].history['val_acc'])
h1=h.reshape((len(nconvs),len(nodes)))
print(h1)
print(h1.shape)
c=0
for i,nc in enumerate(nconvs):
    for j,node in enumerate(nodes):
        if h1[i,j]>c:
            c=h1[i,j]
            convmax=nc
            nodemax=node
print('the best nconvs is {},the best nnode is {}'.format(convmax,nodemax))
print('the maximum val_accuracy is {}'.format(np.max(h1)))
```

```
[[0.8699 0.8719 0.8723]
 [0.8809 0.884  0.8797]
 [0.8843 0.8803 0.8817]]
(3, 3)
the best nconvs is 48,the best nnode is 512
the maximum val_accuracy is 0.8843
```

In [22]:

```
history=[]
nodes=np.array([384,448,512])
nconvs=np.array([40,48,56])
for i,nc in enumerate(nconvs):
    for j,node in enumerate(nodes):
        K.clear_session()
        model = Sequential()
        model.add(Conv2D(nc, (3, 3),
                         padding='valid',
                         input_shape=x_train.shape[1:],
                         activation='relu'))
        #model.add(BatchNormalization())
        #model.add(Conv2D(32, (3, 3), padding='valid', activation='relu'))   #+
        model.add(MaxPooling2D(pool_size=(2, 2)))
        model.add(Dropout(0.15))
        model.add(BatchNormalization())
        model.add(Conv2D(nc, (3, 3), padding='valid', activation='relu'))
        model.add(MaxPooling2D(pool_size=(2, 2)))
```

```
        #model.add(Conv2D(28, (3, 3), padding='valid', activation='relu'))   #+
        #model.add(BatchNormalization())
        model.add(Dropout(0.45))

        model.add(Flatten())
        model.add(BatchNormalization())
        model.add(Dense(node, activation='relu'))
        model.add(BatchNormalization())
        #model.add(Dense(62, activation='relu'))   #+0.01
        #model.add(BatchNormalization())
        model.add(Dropout(0.6))
        model.add(Dense(num_classes, activation='softmax'))
        decay = 0.005/epochs
        opt = keras.optimizers.adam(lr=0.005, decay=decay)
        model.compile(loss='categorical_crossentropy',
              optimizer=opt,
              metrics=['accuracy'])
        print('nc={},node={}'.format(nc,node))
        hist_basic = model.fit(x_train, y_train,batch_size=batch_size,
                               epochs=epochs,validation_data=(x_test, y_test),sh
        history.append(hist_basic)

```

```
nc=40,node=384
Train on 46000 samples, validate on 10000 samples
Epoch 1/8
46000/46000 [==============================] - 82s 2ms/step - loss: 1.
0752 - acc: 0.6863 - val_loss: 0.4895 - val_acc: 0.8375
Epoch 2/8
46000/46000 [==============================] - 75s 2ms/step - loss: 0.
6582 - acc: 0.7842 - val_loss: 0.4107 - val_acc: 0.8603
Epoch 3/8
46000/46000 [==============================] - 79s 2ms/step - loss: 0.
5750 - acc: 0.8083 - val_loss: 0.3882 - val_acc: 0.8663
Epoch 4/8
46000/46000 [==============================] - 81s 2ms/step - loss: 0.
5250 - acc: 0.8217 - val_loss: 0.3738 - val_acc: 0.8697
Epoch 5/8
46000/46000 [==============================] - 81s 2ms/step - loss: 0.
5053 - acc: 0.8291 - val_loss: 0.3694 - val_acc: 0.8748
Epoch 6/8
46000/46000 [==============================] - 82s 2ms/step - loss: 0.
```

In [23]:

```
h=np.zeros((9,1))
for n in range(9):
    h[n]=np.max(history[n].history['val_acc'])
h1=h.reshape((len(nconvs),len(nodes)))
print(h1)
print(h1.shape)
c=0
for i,nc in enumerate(nconvs):
    for j,node in enumerate(nodes):
        if h1[i,j]>c:
            c=h1[i,j]
            convmax=nc
            nodemax=node
print('the best nconvs is {},the best nnode is {}'.format(convmax,nodemax))
print('the maximum val_accuracy is {}'.format(np.max(h1)))
```

```
[[0.8798 0.8818 0.8791]
 [0.8835 0.8836 0.8845]
 [0.8839 0.8836 0.8839]]
(3, 3)
the best nconvs is 48,the best nnode is 512
the maximum val_accuracy is 0.8845
```

In [17]:

```
K.clear_session()
model = Sequential()
model.add(Conv2D(48, (3, 3),
                 padding='valid',
                 input_shape=x_train.shape[1:],
                 activation='relu'))
model.add(MaxPooling2D(pool_size=(2, 2)))
model.add(Dropout(0.15))
model.add(BatchNormalization())
model.add(Conv2D(48, (3, 3), padding='valid', activation='relu'))
model.add(MaxPooling2D(pool_size=(2, 2)))
model.add(Dropout(0.45))
model.add(Flatten())
model.add(BatchNormalization())
model.add(Dense(512, activation='relu'))
model.add(BatchNormalization())
model.add(Dropout(0.6))
model.add(Dense(num_classes, activation='softmax'))
model.compile(loss='categorical_crossentropy',
              optimizer='adadelta',
              metrics=['accuracy'])
print(model.summary())
seed=7
# Fit the model
np.random.seed(seed)
hist_basic = model.fit(x_train, y_train,batch_size=batch_size,epochs=50,validati
print('Done!')
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_1 (Conv2D)            (None, 26, 26, 48)        480
_________________________________________________________________
max_pooling2d_1 (MaxPooling2 (None, 13, 13, 48)        0
_________________________________________________________________
dropout_1 (Dropout)          (None, 13, 13, 48)        0
_________________________________________________________________
batch_normalization_1 (Batch (None, 13, 13, 48)        192
_________________________________________________________________
conv2d_2 (Conv2D)            (None, 11, 11, 48)        20784
_________________________________________________________________
max_pooling2d_2 (MaxPooling2 (None, 5, 5, 48)          0
_________________________________________________________________
dropout_2 (Dropout)          (None, 5, 5, 48)          0
_________________________________________________________________
flatten_1 (Flatten)          (None, 1200)              0
_________________________________________________________________
batch_normalization_2 (Batch (None, 1200)              4800
```