In [39]:
```
%matplotlib inline
import matplotlib.pyplot as plt

import numpy as np
import torch
from torch import autograd
import torch.nn.functional as F

#Prepare the data.
import torch
import numpy as np
from torch.autograd import Variable
import torch.nn as nn
from numpy import linalg as LA

dtype = torch.FloatTensor

images = np.load("./data/images.npy")
labels = np.load("./data/labels.npy")

images = np.reshape(images, (images.shape[0], images.shape[1] * image
s.shape[2]))

images = images - images.mean()
images = images/images.std()

train_seqs = images[0:40000]
val_seqs = images[40000:50000]

train_labels = labels[0:40000]
cv_labels = labels[40000:50000]
```

In [40]:
```
HEIGHT, WIDTH, NUM_CLASSES, NUM_OPT_STEPS, H = 26, 26, 5, 5000, 100
learning_rate = 0.001

class TwoLayerNN(torch.nn.Module):
    def __init__(self, D_in, D_out):
        super(TwoLayerNN, self).__init__()
        #self.Linear = torch.nn.Linear(D_in, D_out)
        self.Linear1 = torch.nn.Linear(D_in, H)
        self.Linear2 = torch.nn.Linear(H, D_out)

    def forward(self, x):
        h = self.Linear1(x)
        h_relu = F.relu(h, inplace=False)
        y_pred = self.Linear2(h_relu)
        return y_pred
```

In [41]:
```
model = TwoLayerNN(HEIGHT * WIDTH, NUM_CLASSES)
```

In [42]:
```
optimizer = torch.optim.Adam(model.parameters(), lr= learning_rate)
```

In [43]:
```
def train(batch_size):
    model.train()

    i = np.random.choice(train_seqs.shape[0], size = batch_size, repl
ace=False)
    x = Variable(torch.from_numpy(train_seqs[i].astype(np.float32)))
    y = Variable(torch.from_numpy(train_labels[i].astype(np.int)))

    optimizer.zero_grad()
    y_hat = model(x)
    loss = F.cross_entropy(y_hat, y)
    loss.backward()
    optimizer.step()

    return loss.data[0]
```

In [44]:
```
def accuracy(y, y_hat):
    count = 0
    for i in range(y.shape[0]):
        if y[i] == y_hat[i]:
            count += 1
    return count/y.shape[0]
```

In [45]:
```
import random
def approx_train_accuracy():
    i = np.random.choice(train_seqs.shape[0], size = 1000, replace=Fa
lse)
    x = train_seqs[i].astype(np.float32)
    y = train_labels[i].astype(np.int)
    y_hat = np.empty(1000)

    lst = list(model.parameters())
    w1 = lst[0].data.numpy()
    b1 = lst[1].data.numpy()
    w2 = lst[2].data.numpy()
    b2 = lst[3].data.numpy()

    for i in range(1000):
        h = x[i].dot(w1.transpose()) + b1
        h_relu = np.maximum(0.0, h)
        y_pred = h_relu.dot(w2.transpose()) + b2
        res = np.argmax(y_pred)
        y_hat[i] = res
    acc = accuracy(y,y_hat)
    return acc

def val_accuracy():
    y_hat = np.empty(1000)

    i = np.random.choice(val_seqs.shape[0], size = 1000, replace=Fals
e)
    x = val_seqs[i].astype(np.float32)
    y = cv_labels[i].astype(np.int)


    lst = list(model.parameters())
    w1 = lst[0].data.numpy()
    b1 = lst[1].data.numpy()
    w2 = lst[2].data.numpy()
    b2 = lst[3].data.numpy()

    for i in range(1000):
        h = x[i].dot(w1.transpose()) + b1
        h_relu = np.maximum(0.0, h)
        y_pred = h_relu.dot(w2.transpose()) + b2
        res = np.argmax(y_pred)
        y_hat[i] = res
    acc = accuracy(y,y_hat)
    return acc
```

In [46]:
```
train_accs, val_accs = [], []
batch_size = 1
for i in range(5000):
    l = train(batch_size)
    if i % 100 == 0:
        train_accs.append(approx_train_accuracy())
        val_accs.append(val_accuracy())
        print("%6d %5.2f %5.2f" % (i, train_accs[-1], val_accs[-1]))
```

```
   0  0.20  0.23
 100  0.60  0.62
 200  0.64  0.61
 300  0.66  0.66
 400  0.71  0.73
 500  0.68  0.71
 600  0.70  0.71
 700  0.74  0.73
 800  0.71  0.72
 900  0.70  0.71
1000  0.71  0.71
1100  0.65  0.71
1200  0.70  0.70
1300  0.74  0.72
1400  0.73  0.71
1500  0.74  0.74
1600  0.73  0.75
1700  0.72  0.71
1800  0.73  0.73
1900  0.71  0.73
2000  0.72  0.73
2100  0.76  0.74
2200  0.77  0.75
2300  0.75  0.72
2400  0.75  0.76
2500  0.73  0.74
2600  0.77  0.75
2700  0.76  0.77
2800  0.75  0.70
2900  0.79  0.78
3000  0.75  0.76
3100  0.75  0.77
3200  0.79  0.78
3300  0.75  0.74
3400  0.75  0.75
3500  0.75  0.76
3600  0.74  0.75
3700  0.78  0.78
3800  0.77  0.80
3900  0.79  0.77
4000  0.74  0.77
4100  0.76  0.78
4200  0.79  0.79
4300  0.74  0.74
4400  0.78  0.76
4500  0.76  0.74
4600  0.78  0.77
4700  0.77  0.76
4800  0.78  0.78
4900  0.76  0.78
```

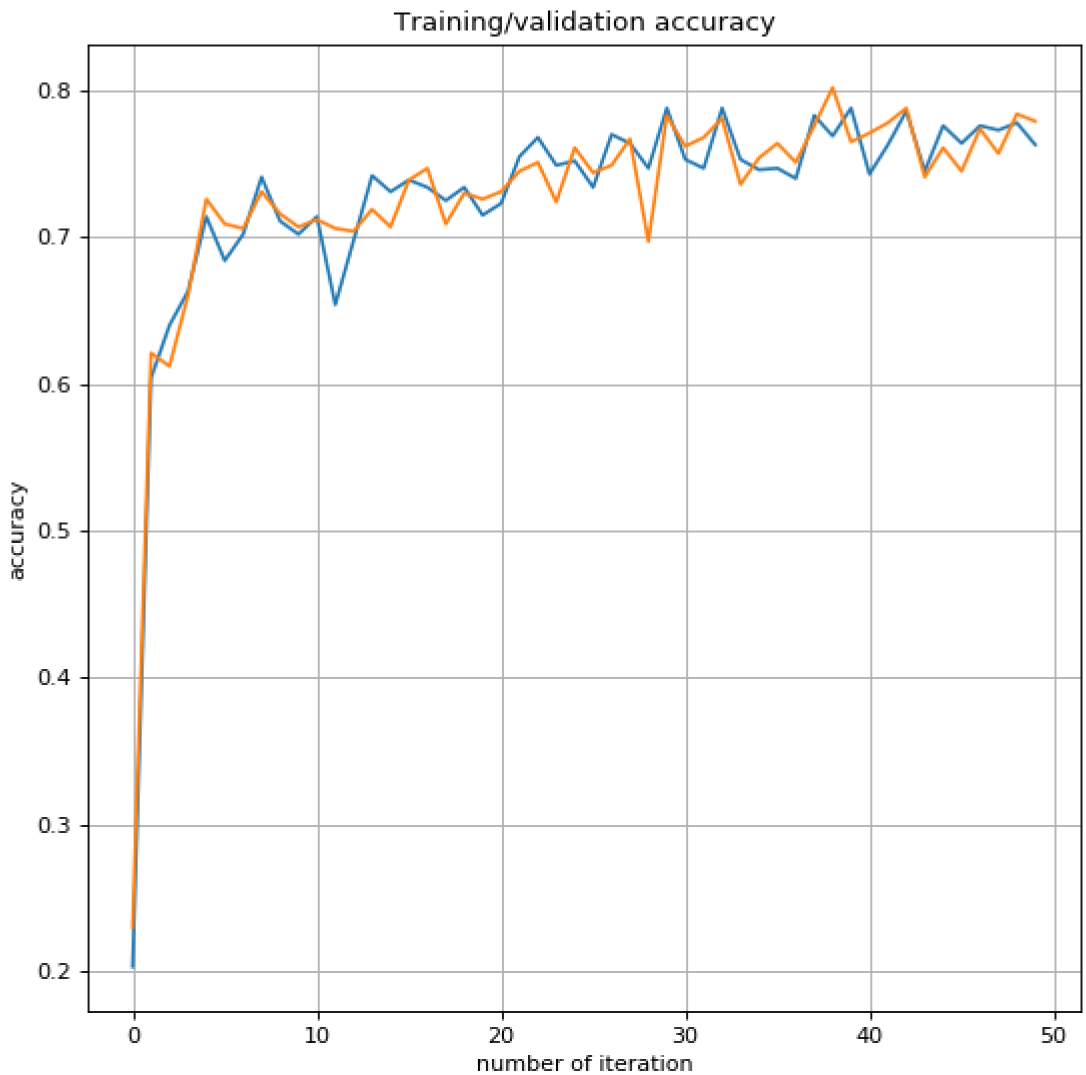
In [47]:
```
import matplotlib.pyplot as plt


t = np.arange(0,len(train_accs),1)

s = train_accs
k = val_accs
print("max_train accuracy: ", max(train_accs))
print("max_val accuracy: ", max(val_accs))
plt.figure(figsize=(8,8), dpi = 80)
plt.plot(t, s, t, k)

plt.xlabel('number of iteration')
plt.ylabel('accuracy')
plt.title('Training/validation accuracy')
plt.grid(True)
plt.show()
```

```
max_train accuracy:  0.788
max_val accuracy:  0.802
```



In [49]:
```
for m in model.children():
    m.reset_parameters()
```

In [50]:
```
train_accs, val_accs = [], []
batch_size = 10
for i in range(5000):
    l = train(batch_size)
    if i % 100 == 0:
        train_accs.append(approx_train_accuracy())
        val_accs.append(val_accuracy())
        print("%6d %5.2f %5.2f" % (i, train_accs[-1], val_accs[-1]))
```

```
   0  0.18  0.20
 100  0.73  0.74
 200  0.74  0.74
 300  0.77  0.77
 400  0.78  0.78
 500  0.77  0.77
 600  0.78  0.80
 700  0.80  0.79
 800  0.81  0.80
 900  0.81  0.82
1000  0.79  0.80
1100  0.81  0.79
1200  0.82  0.81
1300  0.80  0.82
1400  0.83  0.82
1500  0.81  0.81
1600  0.82  0.80
1700  0.82  0.80
1800  0.83  0.83
1900  0.82  0.83
2000  0.83  0.83
2100  0.86  0.84
2200  0.85  0.82
2300  0.81  0.84
2400  0.85  0.83
2500  0.82  0.83
2600  0.83  0.82
2700  0.83  0.82
2800  0.86  0.83
2900  0.84  0.82
3000  0.87  0.83
3100  0.84  0.84
3200  0.85  0.83
3300  0.85  0.83
3400  0.86  0.80
3500  0.86  0.83
3600  0.86  0.83
3700  0.84  0.84
3800  0.86  0.83
3900  0.85  0.84
4000  0.85  0.81
4100  0.86  0.86
4200  0.87  0.84
4300  0.87  0.82
4400  0.88  0.83
4500  0.86  0.82
4600  0.87  0.84
4700  0.88  0.83
4800  0.87  0.82
4900  0.87  0.83
```

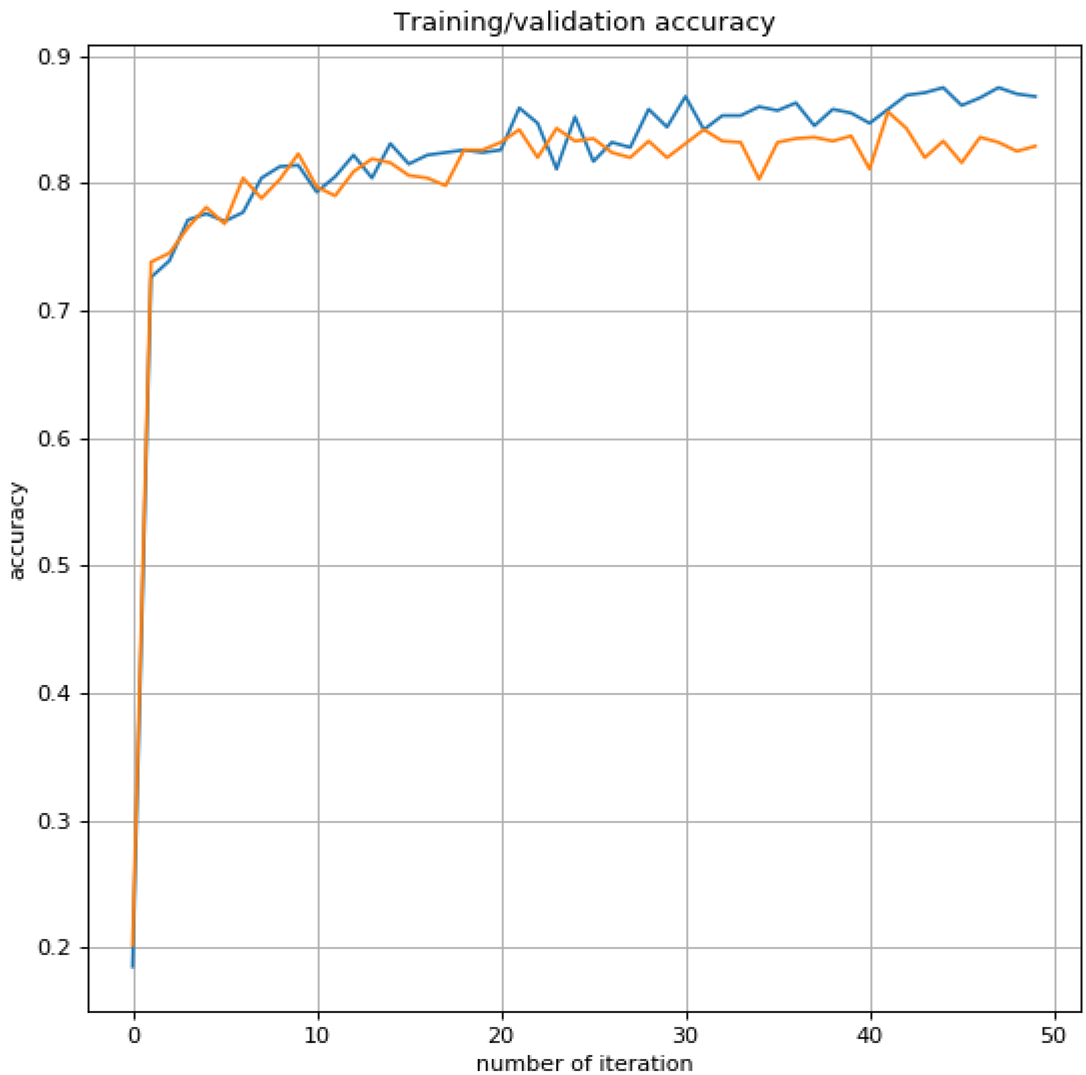
In [51]:
```
import matplotlib.pyplot as plt


t = np.arange(0,len(train_accs),1)

s = train_accs
k = val_accs
print("max_train accuracy: ", max(train_accs))
print("max_val accuracy: ", max(val_accs))
plt.figure(figsize=(8,8), dpi = 80)
plt.plot(t, s, t, k)

plt.xlabel('number of iteration')
plt.ylabel('accuracy')
plt.title('Training/validation accuracy')
plt.grid(True)
plt.show()
```

```
max_train accuracy:  0.875
max_val accuracy:  0.856
```



In [91]:
```
for m in model.children():
    m.reset_parameters()
optimizer = torch.optim.Adam(model.parameters(), lr= 0.0001)

train_accs, val_accs = [], []
batch_size = 500
for i in range(10000):
    l = train(batch_size)
    if i % 100 == 0:
        train_accs.append(approx_train_accuracy())
        val_accs.append(val_accuracy())
        print("%6d %5.2f %5.2f" % (i, train_accs[-1], val_accs[-1]))
```

```
   0  0.19  0.20
 100  0.74  0.74
 200  0.77  0.77
 300  0.79  0.79
 400  0.79  0.78
 500  0.79  0.84
 600  0.83  0.82
 700  0.81  0.81
 800  0.83  0.83
 900  0.81  0.82
1000  0.82  0.81
1100  0.84  0.84
1200  0.86  0.83
1300  0.84  0.85
1400  0.81  0.84
1500  0.85  0.83
1600  0.85  0.84
1700  0.85  0.83
1800  0.84  0.84
1900  0.87  0.82
2000  0.86  0.83
2100  0.86  0.84
2200  0.88  0.84
2300  0.86  0.87
2400  0.89  0.86
2500  0.89  0.83
2600  0.89  0.82
2700  0.89  0.84
2800  0.88  0.87
2900  0.86  0.86
3000  0.88  0.87
3100  0.90  0.86
3200  0.91  0.86
3300  0.87  0.87
3400  0.90  0.86
3500  0.90  0.86
3600  0.90  0.85
3700  0.88  0.86
3800  0.89  0.85
3900  0.89  0.86
4000  0.90  0.85
4100  0.89  0.86
4200  0.89  0.88
4300  0.90  0.87
4400  0.92  0.85
4500  0.88  0.85
4600  0.90  0.85
4700  0.91  0.87
4800  0.91  0.85
4900  0.90  0.86
5000  0.91  0.88
5100  0.92  0.86
5200  0.92  0.85
5300  0.93  0.88
5400  0.91  0.86
5500  0.92  0.88
5600  0.91  0.85
```

```
5700  0.92  0.86
5800  0.93  0.86
5900  0.92  0.85
6000  0.91  0.86
6100  0.94  0.85
6200  0.94  0.85
6300  0.93  0.89
6400  0.92  0.87
6500  0.93  0.87
6600  0.90  0.85
6700  0.94  0.87
6800  0.93  0.88
6900  0.93  0.87
7000  0.92  0.87
7100  0.92  0.88
7200  0.94  0.85
7300  0.94  0.88
7400  0.94  0.87
7500  0.93  0.89
7600  0.93  0.87
7700  0.95  0.87
7800  0.93  0.88
7900  0.95  0.87
8000  0.94  0.86
8100  0.94  0.85
8200  0.95  0.88
8300  0.93  0.88
8400  0.94  0.87
8500  0.94  0.87
8600  0.94  0.87
8700  0.94  0.87
8800  0.94  0.87
8900  0.94  0.88
9000  0.95  0.87
9100  0.95  0.86
9200  0.94  0.87
9300  0.94  0.86
9400  0.95  0.88
9500  0.93  0.86
9600  0.95  0.87
9700  0.95  0.87
9800  0.94  0.87
9900  0.94  0.87
```

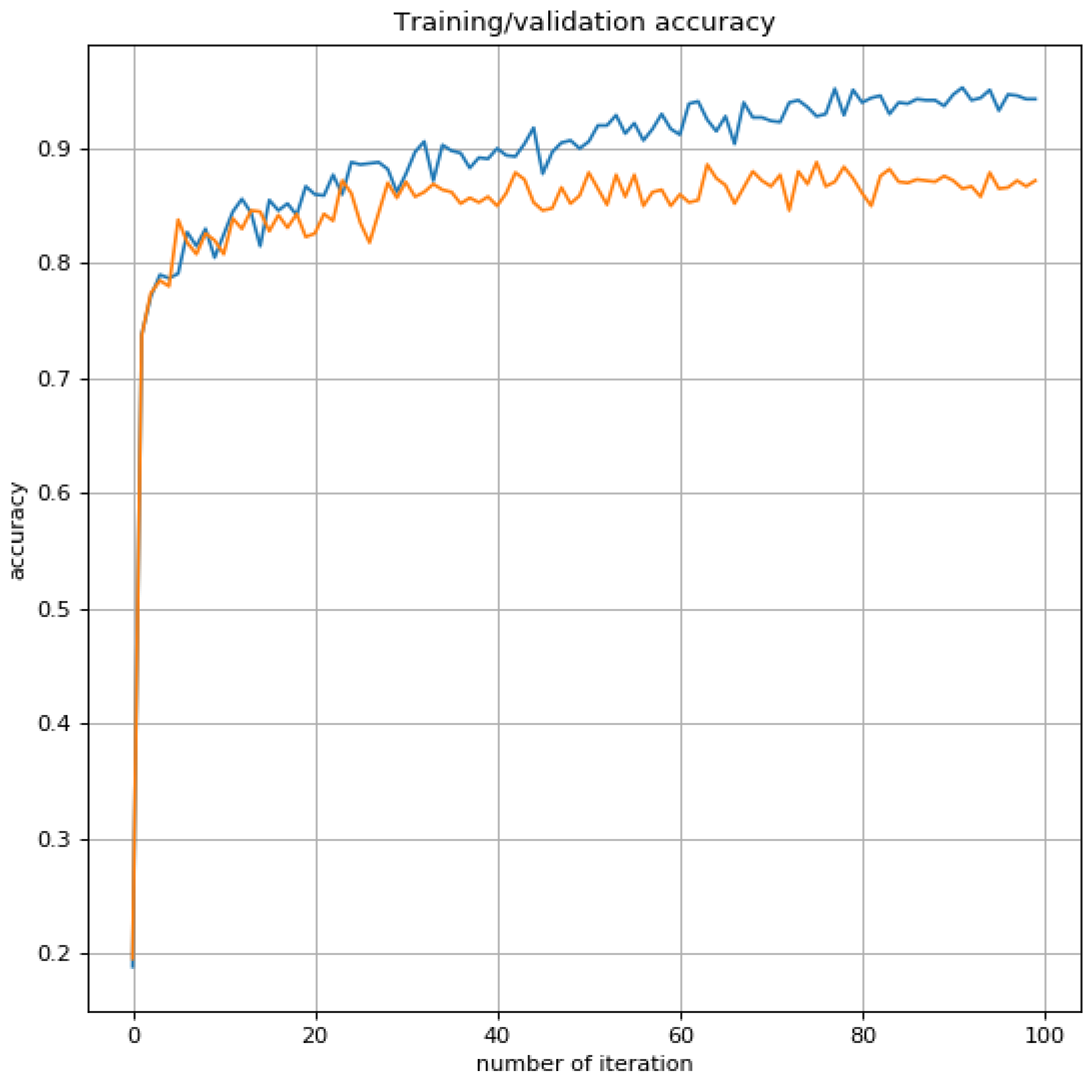
In [92]:
```
import matplotlib.pyplot as plt


t = np.arange(0,len(train_accs),1)

s = train_accs
k = val_accs
print("max_train accuracy: ", max(train_accs))
print("max_val accuracy: ", max(val_accs))
plt.figure(figsize=(8,8), dpi = 80)
plt.plot(t, s, t, k)

plt.xlabel('number of iteration')
plt.ylabel('accuracy')
plt.title('Training/validation accuracy')
plt.grid(True)
plt.show()
```

```
max_train accuracy:  0.953
max_val accuracy:  0.888
```



Best Validation Accuracy:

The best validation accuracy reached = 88% at,

learning rate = 0.0001

Optimizer = Adam

Batch size = 500

Number of optimization steps = 10000

Time taken to complete : 1 minute

The model clearly overfits here. I'm able to reach 87% validation accuracy (at lr = 0.001, batch size = 20, Optimization steps = 5000), anything beyond this, the model clearly overfits with high training accuracy.