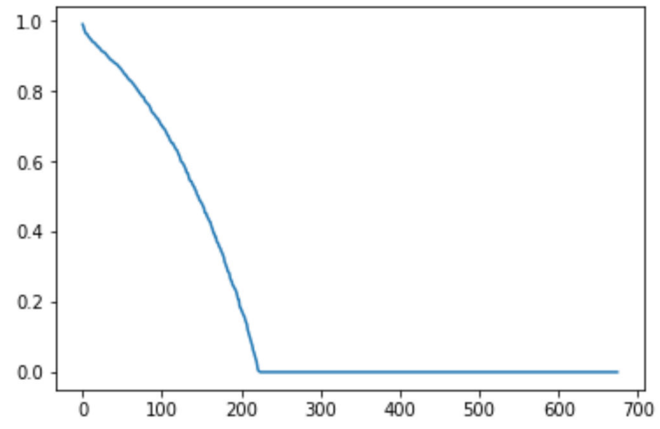
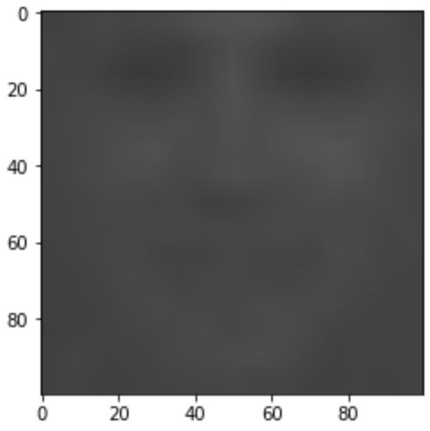
In [3]:
```python
import pickle
import os
from scipy.linalg import eig
from scipy.linalg import sqrtm
from scipy.linalg import inv
import numpy as np
from numpy.linalg import svd
import matplotlib.pyplot as plt
from sklearn.preprocessing import StandardScaler
import cv2
import random

def plot_image(vector):
    vector = ((vector + 1.0) / 2.0) * 255.0
    vector = np.reshape(vector, (15, 15, 3))
    p = vector.astype("uint8")
    p = cv2.resize(p, (100, 100))
    count = 0
    plt.imshow(p)
    plt.show()

DATA_DIR = "hw05-data"
d = 15 * 15 * 3

x_train = [((i / 255) * 2.0 - 1.0).flatten().reshape(d, 1) for i in pickle.load( op
en(os.path.join(DATA_DIR,"x_train.p"), "rb") )]
y_train = [((i / 255) * 2.0 - 1.0).flatten().reshape(d, 1) for i in pickle.load( op
en(os.path.join(DATA_DIR,"y_train.p"), "rb") )]
x_test = [((i / 255) * 2.0 - 1.0).flatten().reshape(d, 1) for i in pickle.load( ope
n(os.path.join(DATA_DIR,"x_test.p"), "rb") )]
y_test = [((i / 255) * 2.0 - 1.0).flatten().reshape(d, 1) for i in pickle.load( ope
n(os.path.join(DATA_DIR,"y_test.p"), "rb") )]

n = len(x_train)
Sxx = np.zeros( (d, d), "float" )
Syy = np.zeros( (d, d), "float" )
Sxy = np.zeros( (d, d), "float" )

for i in range(n):
    x_mean = np.mean(x_train[i])
    y_mean = np.mean(y_train[i])
    Sxx += np.matmul( (x_train[i] - x_mean), (x_train[i] - x_mean).T)
    Syy += np.matmul( (y_train[i] - y_mean), (y_train[i] - y_mean).T)
    Sxy += np.matmul( (x_train[i] - x_mean), (y_train[i] - y_mean).T)

Sxx /= n
Syy /= n
Sxy /= n

I = np.identity( d, "float")
lamb = 0.00001

M = inv(sqrtm(Sxx + lamb * I)).dot(Sxy).dot(inv(sqrtm(Syy + lamb * I)))
U, s, V = svd(M)
plt.figure()
plt.plot(s)
plt.show()
```



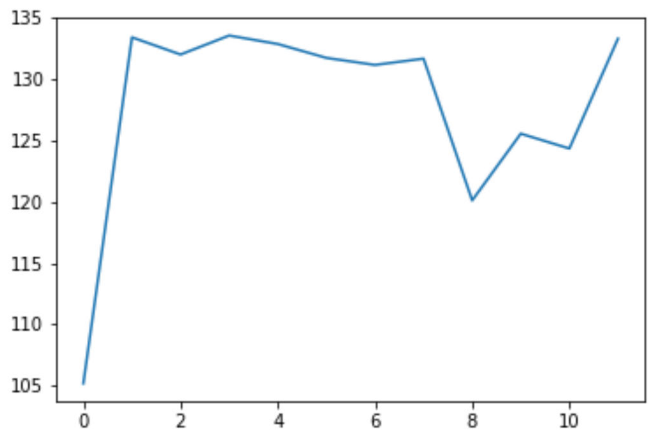
```
In [46]: plot_image(U[:, 0] + np.mean(x_train[0]))
```

```
/home/taflab/.local/lib/python3.5/site-packages/ipykernel_launcher.py:16: Comple
xWarning: Casting complex values to real discards the imaginary part
  app.launch_new_instance()
```



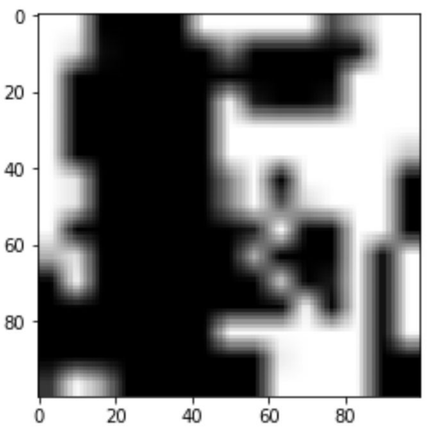
In [47]:
```
k = [0, 50, 100, 150, 200, 250, 300, 350, 400, 450, 500, 650]
Pk = U[:, k]

X = np.concatenate(tuple([i.T for i in x_train]))
Y = np.concatenate(tuple([i.T for i in y_train]))
XPk = np.matmul(X, Pk)

I = np.identity(XPk.shape[1])
w = np.matmul( inv( np.matmul(XPk.T, XPk) + lamb * I), np.matmul(XPk.T, Y) )

X_test = np.concatenate(tuple([i.T for i in x_test]))
Y_test = np.concatenate(tuple([i.T for i in y_test]))

error = np.zeros(len(k), "float")
for i in range(len(k)):
    Pi = Pk[:, i].reshape(675, 1)
    wi = w[i, :].reshape(1,675)
    Y_estimate = X_test.dot(Pi).dot(wi)
    error[i] = np.sum((Y_test - Y_estimate) ** 2) / len(Y_diff)

plt.figure()
plt.plot(error)
plt.show()
```

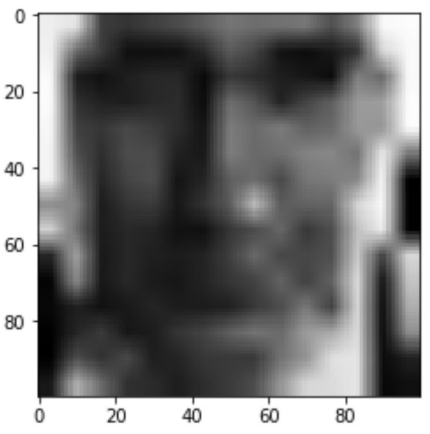
```
/home/taflab/.local/lib/python3.5/site-packages/ipykernel_launcher.py:19: Comple
xWarning: Casting complex values to real discards the imaginary part
```



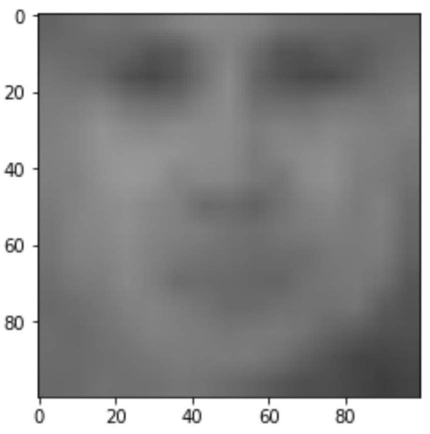
In [52]:
```
random.seed(5)
lst = [random.randint(0, 254) for _ in range(4)]
print(lst)

for i in lst:
    print("Image " + str(i))
    X = x_test[i].T
    plot_image(X)
    Y = y_test[i].T
    plot_image(Y)
    Y_predicted = X.dot(Pk).dot(w)
#     Y_predicted = X.dot(Pk[:, 3].reshape(675, 1)).dot(w[3, :].reshape(1, 675))
    plot_image(Y_predicted)
```

```
[159, 65, 189, 91]
Image 159
```

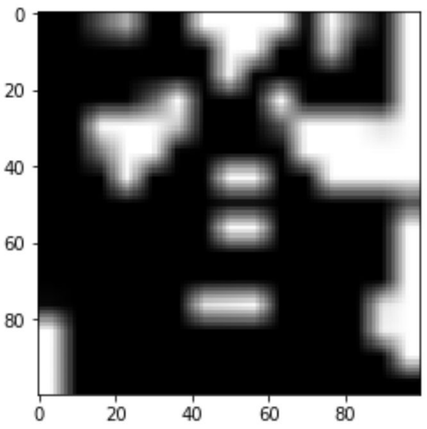


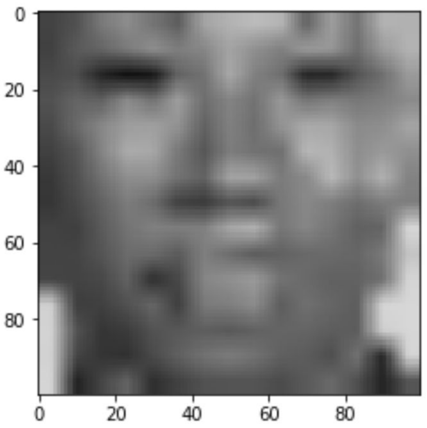


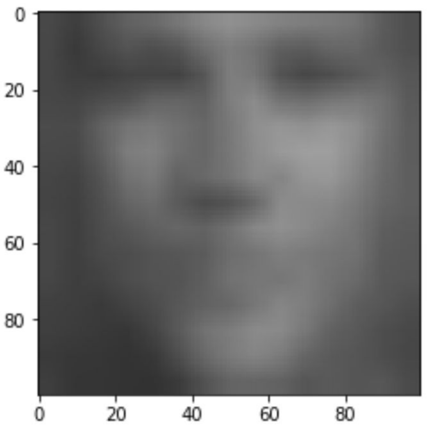
```
/home/taflab/.local/lib/python3.5/site-packages/ipykernel_launcher.py:16: Comple
xWarning: Casting complex values to real discards the imaginary part
  app.launch_new_instance()
```



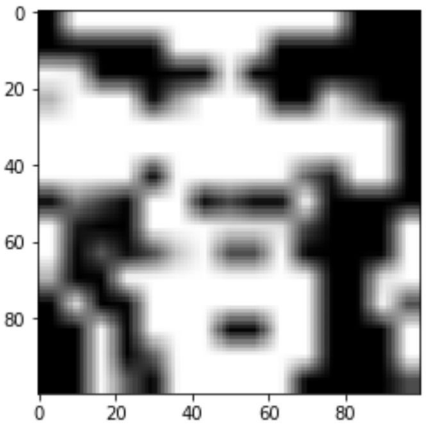
```
Image 65
```

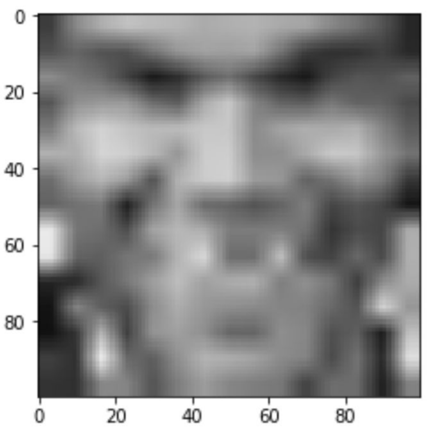






```
Image 189
```

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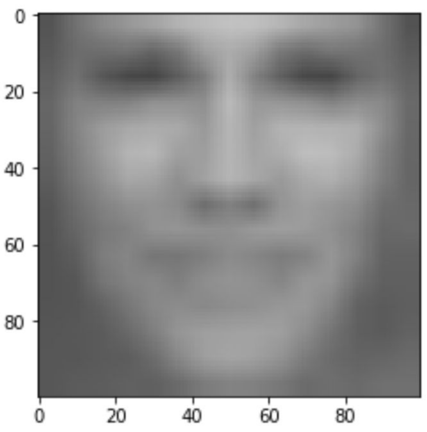
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Image 91
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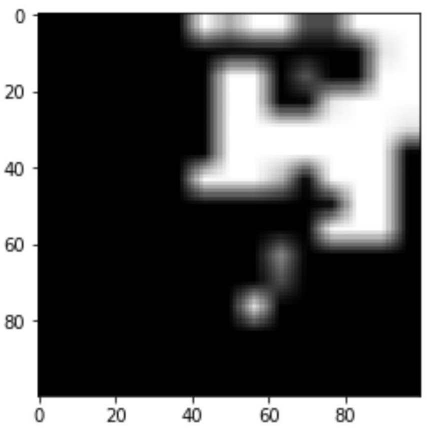
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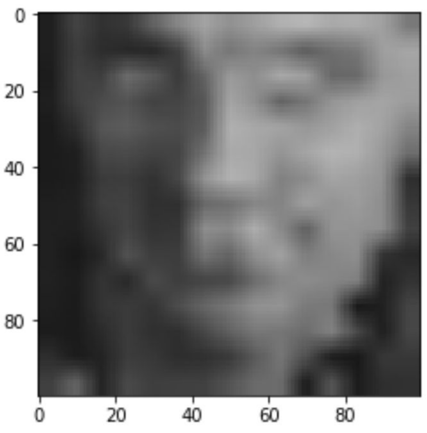
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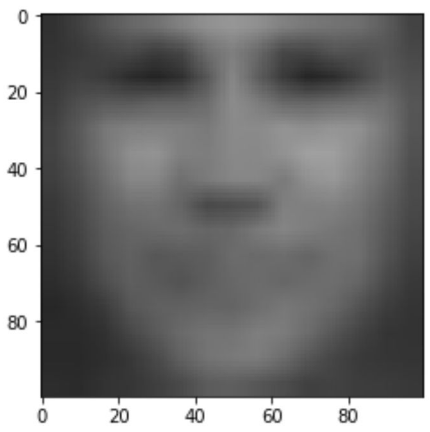
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