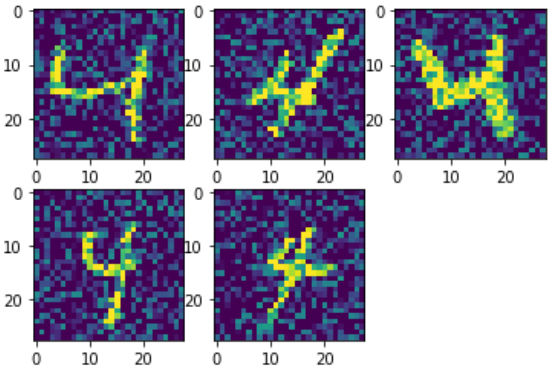
```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
```

Part a

```
data=pd.read_csv("/content/mnist.xls")
```

```
data_n=np.array(data)
```

```
for i in range(5):
  image=np.reshape(data_n[i], (  int(data_n.shape[1]**(1/2)), int(data_n.shape[1]**(1/2)) ))
  plt.subplot(2,3,i+1)
  plt.imshow(image)
```



Answer

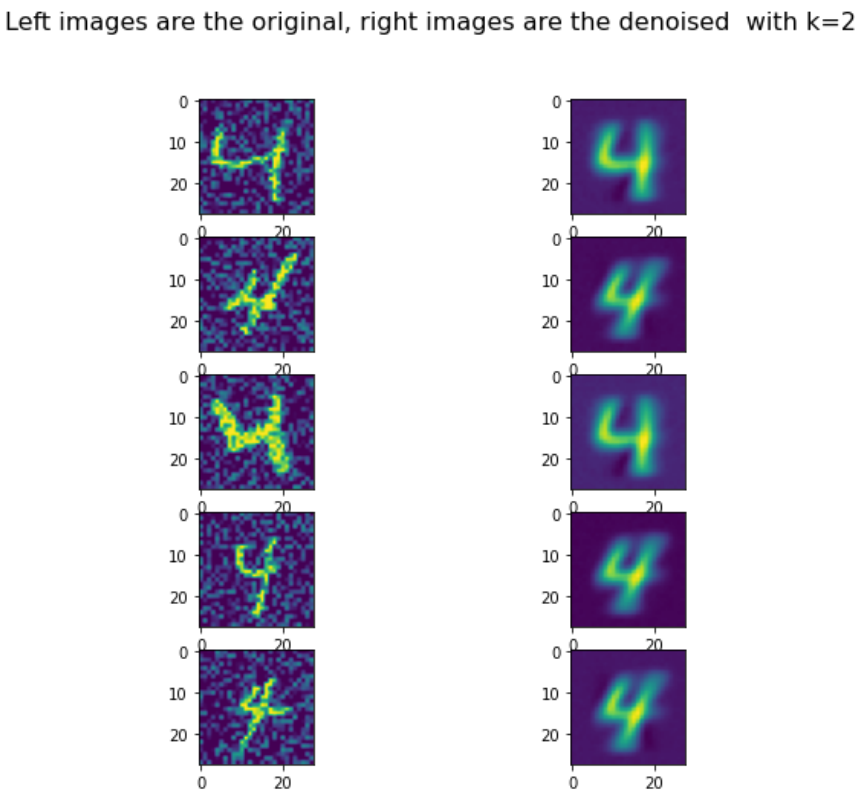
1) What numbers displayed in these images? **The plotted images are all 4.**

2)Are the images clear or noisy? **The images are noisy.**

Part b

```
u,s,vt=np.linalg.svd(data_n)
```

```
k=2
data_reco=u[:,0:k].dot(np.diag(s[0:k])).dot(vt[0:k,:])

fig=plt.figure(figsize=(8,8))
fig.suptitle('Left images are the original, right images are the denoised  with k=2', fontsize=16)

for i in range(5):
  image=np.reshape(data_n[i], (  int(data_n.shape[1]**(1/2)), int(data_n.shape[1]**(1/2)) ))
  reco_image=np.reshape(data_reco[i], (  int(data_reco.shape[1]**(1/2)), int(data_reco.shape[1]**(1/2)) ))
  plt.subplot(5,2,2*i+1)
  plt.imshow(image)
  plt.subplot(5,2,2*(i+1))
  plt.imshow(reco_image)
```



Answer

1) How do the shapes of the digits in the denoised images compare to the original noisy images?

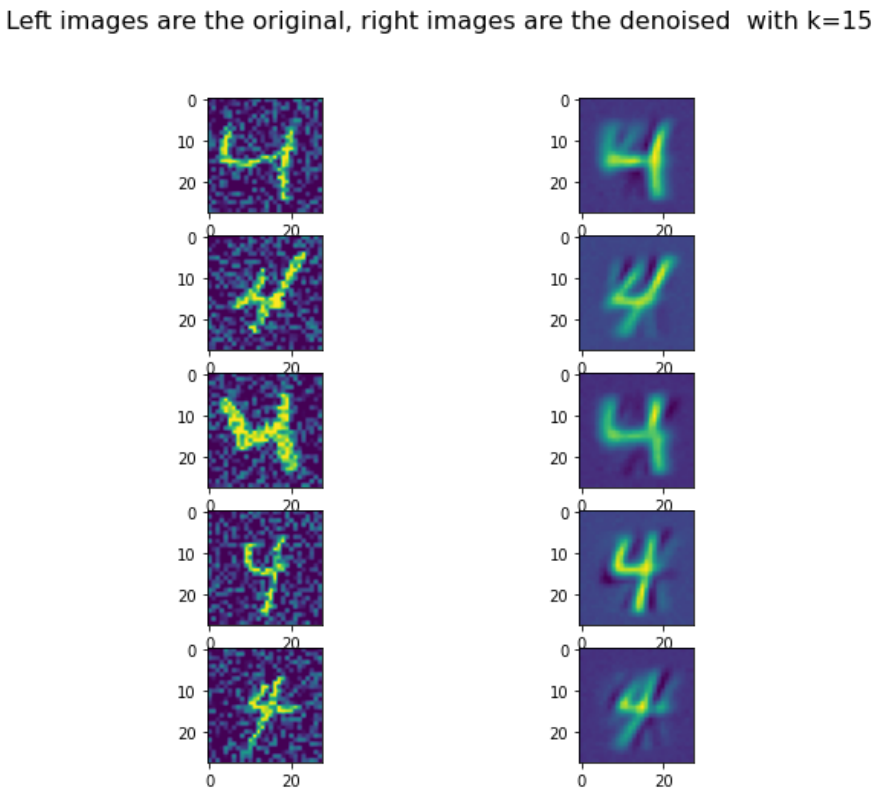
The shapes look blurred compared to the original ones. Also, the third image we notice that the denoised number four shape is not as tilted as the noisy image. Furthermore the last two denoised images look very similar one to the other.With k=2 we have captured the most important information.

2) How do the edges of the image compare to the original noisy images? **Practically all noise around the number 4 has been eliminated compared to the original, and we do not have any dots at the edges of the image. The number edges look blurred in the denoised images, while the original do not. With k=2 we have captured the most important information.**

Part c

```
u,s,vt=np.linalg.svd(data_n)


k=15
data_reco=u[:,0:k].dot(np.diag(s[0:k])).dot(vt[0:k,:])


fig2=plt.figure(figsize=(8,8))
fig2.suptitle('Left images are the original, right images are the denoised  with k=15', fontsize=16)

for i in range(5):
  image=np.reshape(data_n[i], (  int(data_n.shape[1]**(1/2)), int(data_n.shape[1]**(1/2)) ))
  reco_image=np.reshape(data_reco[i], (  int(data_reco.shape[1]**(1/2)), int(data_reco.shape[1]**(1/2)) ))
  plt.subplot(5,2,2*i+1)
  plt.imshow(image)
```

```
    plt.subplot(5,2,2*(i+1))
    plt.imshow(reco_image)
```



Answer

1)How do the shapes of the digits in the denoised images compare to the original noisy images?

The shapes look blurred compared to the original ones. Also, some extra tenuous lines are shown in the new plots of the denoised images.

2) How do the edges of the image compare to the original noisy images?

The edges of the image of the denosied plots have some noise but not as much as the original . The number edges are blurred in the denoised plots compared to the original and the denoised numbers are not as well as delimited as the original noisy ones.

3) Additionally, compare your denoised images using k=15 to your results under k=2.

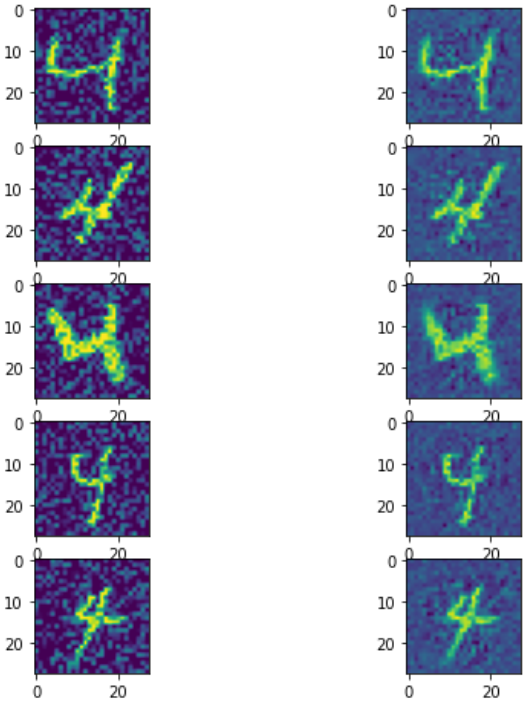
From k=2 to k=15 it is clearly shown that noise is added. Extra tenuous lines are included. Using k=15 the numbers are slightly less blurred than when using k=2

Part d

```
u,s,vt=np.linalg.svd(data_n)


k=250
data_reco=u[:,0:k].dot(np.diag(s[0:k])).dot(vt[0:k,:])


fig3=plt.figure(figsize=(8,8))
fig3.suptitle('Left images are the original, right images are the denoised  with k=250', fontsize=16)

for i in range(5):
  image=np.reshape(data_n[i], (  int(data_n.shape[1]**(1/2)), int(data_n.shape[1]**(1/2)) ))
  reco_image=np.reshape(data_reco[i], (  int(data_reco.shape[1]**(1/2)), int(data_reco.shape[1]**(1/2)) ))
```

```
    plt.subplot(5,2,2*i+1)
    plt.imshow(image)
    plt.subplot(5,2,2*(i+1))
    plt.imshow(reco_image)
```

```
Left images are the original, right images are the denoised  with k=250
```



Answer

1)How do the shapes of the digits in the denoised images compare to the original noisy images?

The shapes of the denoised and original now are almost the same. They look pretty similar. The numbers do not longer look blurred in the denoised plots.

2)How do the edges of the image compare to the original noisy images?

The oiriginal and the denoised look similar at the edges. The denoised look with lighter saturation.Now in the denoised image there is considerable noise around the number. The edges of the numbers now are not blurred as in the original.

3)Additionally, compare your denoised images using $k = 250$ to your results under $k = 2$ and $k = 15$ **From k=15 to k=250 the noisy tenuous lines are not longer present and the number is not blurred. From k=2 to k=250 the blureness of the number edges is not longer present. For both cases there is increase amount of noise around the number 4.**

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