```
import numpy as np
from scipy.ndimage import gaussian_laplace, rank_filter, generic_filter
import skimage
import matplotlib.pyplot as plt
import cv2
import time
```

```
from matplotlib.patches import Circle
def show_all_circles(loc,image, cx, cy, sig, color='r'):
    """
    image: numpy array, representing the grayscsale image
    cx, cy: numpy arrays or lists, centers of the detected blobs
    rad: numpy array or list, radius of the detected blobs
    """
    fig, ax = plt.subplots()
    ax.set_aspect('equal')
    ax.imshow(image, cmap='gray')
    for x, y, s in zip(cx, cy, sig):
        circ = Circle((x, y), s*(2**0.5), color=color, fill=False)
        ax.add_patch(circ)

    plt.title('%i circles' % len(cx))
    #plt.savefig(loc)
    plt.show()
```

```
img_dir = "data/"
img_list = ["butterfly.jpg","einstein.jpg","sunflowers.jpg","fishes.jpg","2.jpg","cat.jpg","dog.jpg","dice.jpg"]
```

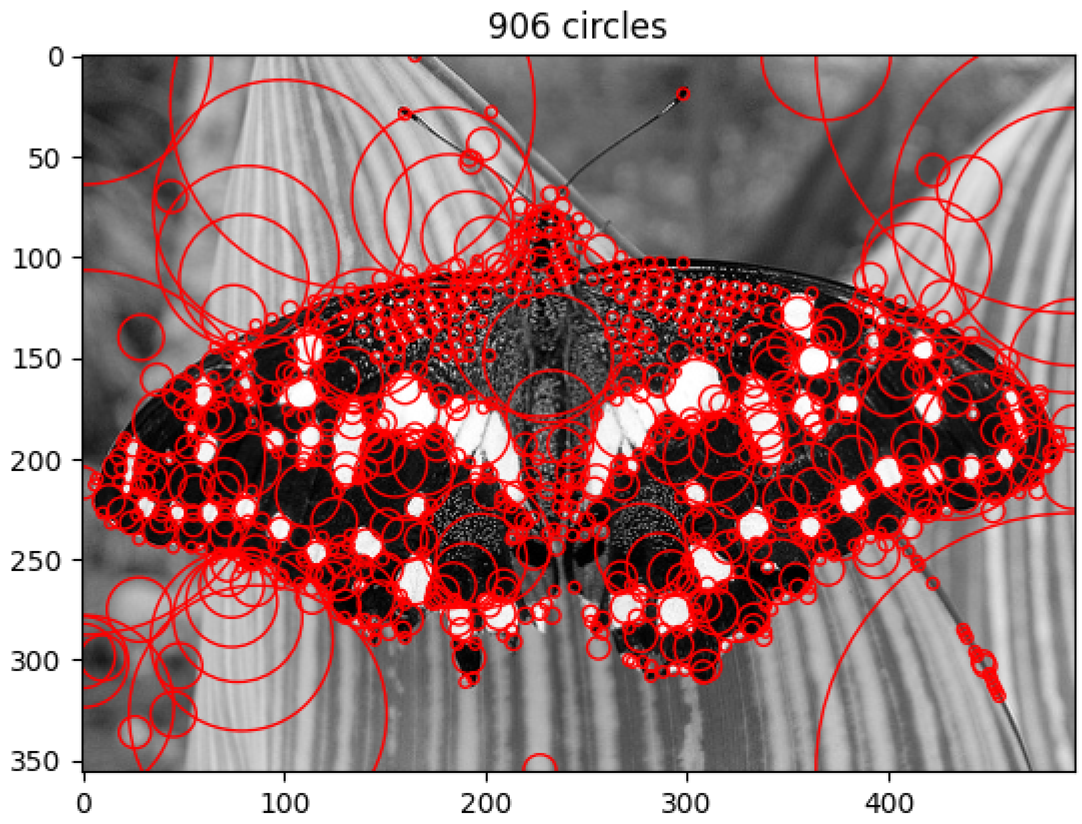
```
def increase_filter(img):
    start_time = time.time()
    h,w = img.shape
    sigma = 2.0
    k = 2**0.5
    scale_list = np.empty((h, w, 12))
    for i in range(12):
        normalized = sigma**2*gaussian_laplace(img,sigma)
        normalized = sigma**2*gaussian_laplace(img,sigma)
        scale_list[:,:,i] = normalized**2
        sigma*= k
    end_time = time.time()
    print("increase filter",end_time-start_time)
    return scale_list
```

```
def downsample(img):
    start_time = time.time()
    h,w = img.shape
    k = 2**0.5
    sigma = 2.0
    scale_list = np.empty((h, w, 12))
    for i in range(12):
        img = skimage.transform.resize(img,(int(h/pow(k,i)), int(w/pow(k,i))))
        normalized = sigma**2*gaussian_laplace(img,sigma)
        scale_list[:,:,i]= skimage.transform.resize(normalized**2,(h,w))
    end_time = time.time()
    print("downsample",end_time-start_time)
    return scale_list
```

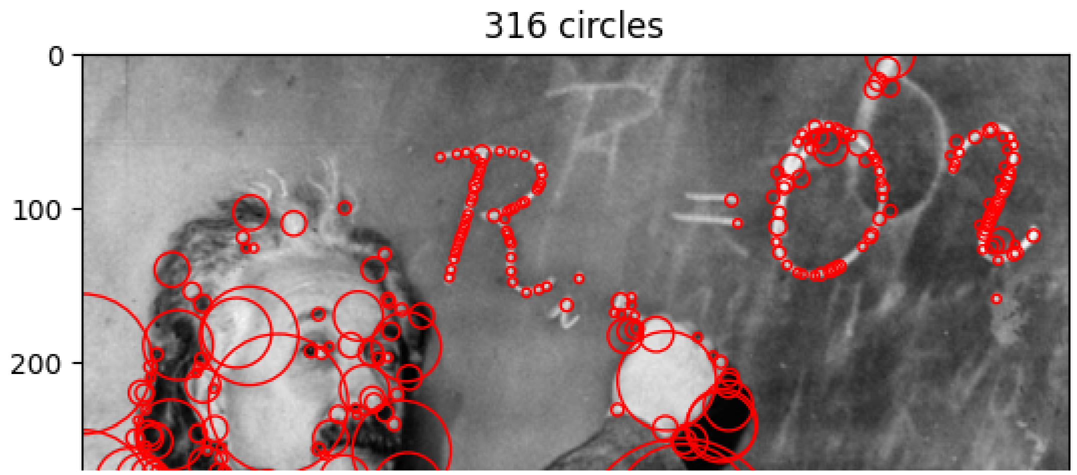
```
def nms(scale_list):
    h,w,_ = scale_list.shape
    local_max = np.empty((h, w, 12))
    maxima = []
    for i in range(12):
        local_max[:,:,i] = rank_filter(input=scale_list[:,:,i],rank=-1,size=(3,3))
    # for i in range(12):
    #         maxx = lambda a:np.amax(a)
    #         local_max[:,:,i] = generic_filter(scale_list[:,:,i], maxx, (3, 3))
    for i in range(h):
        for j in range(w):
            maxx = max(local_max[i,j,:])
            idx = np.argmax(local_max[i,j,:])
            if maxx == scale_list[i][j][idx] and maxx >= 0.02:
                maxima.append((i,j,idx))

    cx,cy,sig = [],[],[]
    for i,j,level in maxima:
        cx.append(j)
        cy.append(i)
        sig.append(2.0*((2**0.5)**level))

    return cx,cy,sig
```

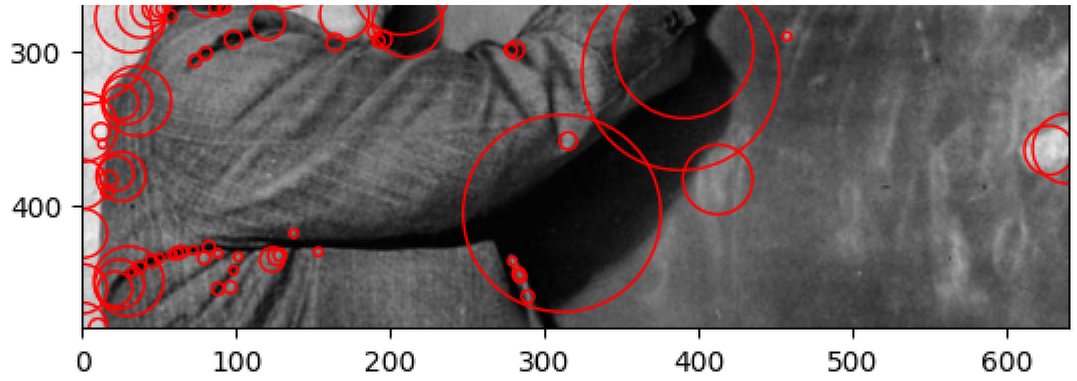
```
for loc in img_list:
    img = cv2.imread(img_dir+loc,cv2.IMREAD_GRAYSCALE).astype(np.float64)
    img/= 255
    cx,cy,sig = nms(increase_filter(img))
    _ = downsample(img)
    show_all_circles(loc,img,cx,cy,sig)
```

```
increase filter 0.6730060577392578
downsample 0.10200023651123047
```



```
increase filter 1.1540071964263916
downsample 0.18301105499267578
```





```
increase filter 0.44899845123291016
downsample 0.06700563430786133
```

664 circles