In [2]:
```
%matplotlib inline
import os
import sys
import numpy as np
import matplotlib
import matplotlib.pyplot as plt
from PIL import Image
import timeit
import cv2
import scipy
from scipy.ndimage import convolve
from scipy.ndimage import gaussian_laplace
from scipy.ndimage import rank_filter
import skimage
from skimage.feature import peak_local_max, blob_dog, blob
import time
```

In [3]:
```
def show_all_circles(image, cx, cy, rad, IMG_NAME, 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
    """
    import matplotlib.pyplot as plt
    from matplotlib.patches import Circle

    fig, ax = plt.subplots()
    ax.set_aspect('equal')
    ax.imshow(image, cmap='gray')
    for x, y, r in zip(cx, cy, rad):
        circ = Circle((x, y), r, color=color, fill=False)
        ax.add_patch(circ)

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

In [4]:
```
def read_image(IMG_NAME):
    # YOUR CODE HERE
    gray=np.asarray(Image.open(IMG_NAME).convert('L'))/255
    return gray
```

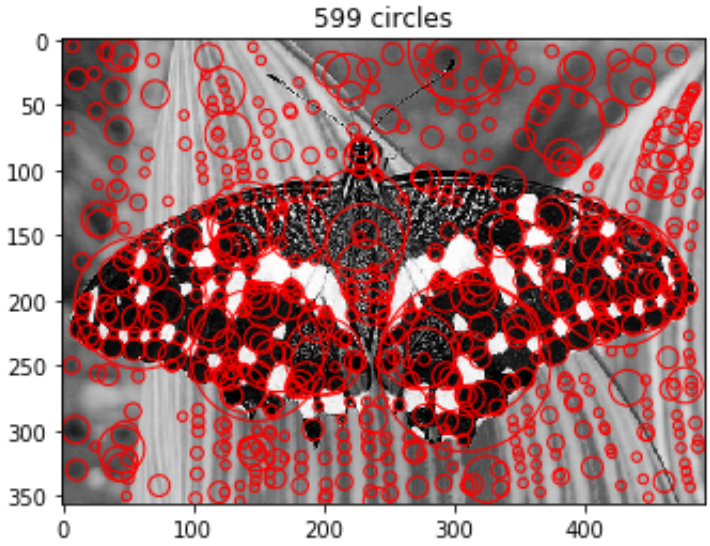
In [5]:
```
def increase_filter_image_iteratiion(IMG,sigma_initial, n, multi_factor):

    h, w = IMG.shape

    scale_space = np.empty((h,w,n)) # [h,w] - dimensions of image, n - number of levels in scale space
    scale_fact = 1
    r = []
    for i in range(n):
        sigma=sigma_initial*multi_factor**i
        r.append(np.sqrt(2)*sigma)
        scale_space[:,:,i] = sigma**2*gaussian_laplace(IMG,sigma)

    return scale_space, np.array(r)
```

In [6]:
```
def downsample_image_iteratiion(IMG,sigma_initial, n, multi_factor):

    h, w = IMG.shape
    sigma = sigma_initial
    scale_space = np.empty((h,w,n)) # [h,w] - dimensions of image, n - number of levels in scale space
    r = []
    orig_img = IMG
    k = multi_factor
    for i in range(n):
        down_scale_factor=1/multi_factor**i
        r.append(np.sqrt(2)*sigma/down_scale_factor)
        h_new = int(IMG.shape[0]*down_scale_factor)
        w_new = int(IMG.shape[1]*down_scale_factor)
        down_scale_img = skimage.transform.resize(IMG,(h_new,w_new),mode='reflect',anti_aliasing=True)
        filter_img = gaussian_laplace(down_scale_img,sigma)
        scale_space[:,:,i] = skimage.transform.resize(filter_img**2,(h,w),mode='reflect',anti_aliasing=True)
    return scale_space, np.array(r)
```

In [7]:
```
def nonmaximum_suppression(img_stack,thres_hold):

    non_max_return = np.zeros([img_stack.shape[0],img_stack.shape[1],i
mg_stack.shape[2]])
    peak_index= peak_local_max(scale_space)
    non_max_return[peak_index[:,0],peak_index[:,1],peak_index[:,2]] =
img_stack[peak_index[:,0],peak_index[:,1],peak_index[:,2]]
    thred = np.where(non_max_return>thres_hold,non_max_return,0)
    position = np.nonzero(thred)


    return position
```

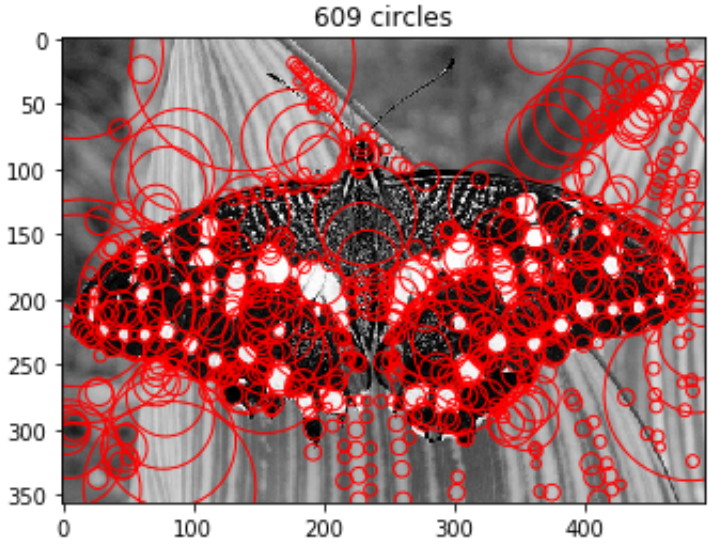
In [8]:
```
# Increase Filter size
IMG_FOLDER = 'part2_images/'
IMG_NAME = 'butterfly.jpg'
out_folder = 'output/'
initial_sigma = 2
num_iter = 15
factor = 1.3
thred = 0.0015
img = read_image(IMG_FOLDER + IMG_NAME)
start_time = time.time()
scale_space ,r  = increase_filter_image_iteratiion(img,initial_sigma,n
um_iter,factor)
position= nonmaximum_suppression(scale_space, thred)
end_time = time.time()
cx = position[1]
cy = position[0]
rad = r[position[2]]
print('Time elapse = ', end_time-start_time)
show_all_circles(img, cx, cy, rad,out_folder+ 'UpSample_'+IMG_NAME)
```

```
Time elapse =  1.2248668670654297
```



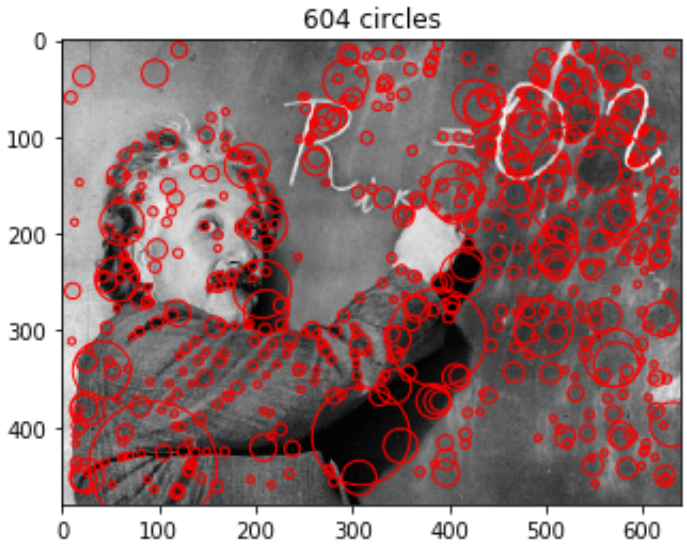
In [9]:
```
# Downsample images
IMG_FOLDER = 'part2_images/'
IMG_NAME = 'butterfly.jpg'
out_folder = 'output/'


initial_sigma = 2
num_iter = 15
factor = 1.3
thred = 0.00075
img = read_image(IMG_FOLDER + IMG_NAME)
start_time = time.time()
scale_space ,r  = downsample_image_iteratiion(img,initial_sigma,num_it
er,factor)
position= nonmaximum_suppression(scale_space,thred)
end_time = time.time()
cx = position[1]
cy = position[0]
rad = r[position[2]]
print('Time elapse = ', end_time-start_time)
show_all_circles(img, cx, cy, rad,out_folder+'DownSample_'+IMG_NAME)
```

```
Time elapse =  0.45403385162353516
```



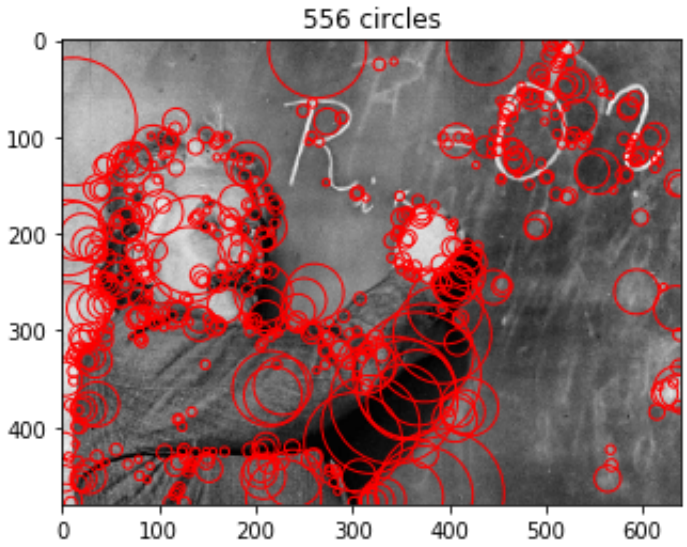
In [11]:
```
# Increase Filter size
IMG_FOLDER = 'part2_images/'
IMG_NAME = 'einstein.jpg'
out_folder = 'output/'
initial_sigma = 2
num_iter = 15
factor = 1.3
thred = 0.025
img = read_image(IMG_FOLDER + IMG_NAME)
start_time = time.time()
scale_space ,r  = increase_filter_image_iteratiion(img,initial_sigma,n
um_iter,factor)
position= nonmaximum_suppression(scale_space, thred)
end_time = time.time()
cx = position[1]
cy = position[0]
rad = r[position[2]]
print('Time elapse = ', end_time-start_time)
show_all_circles(img, cx, cy, rad,out_folder+ 'UpSample_'+IMG_NAME)
```

```
Time elapse =  2.1719589233398438
```



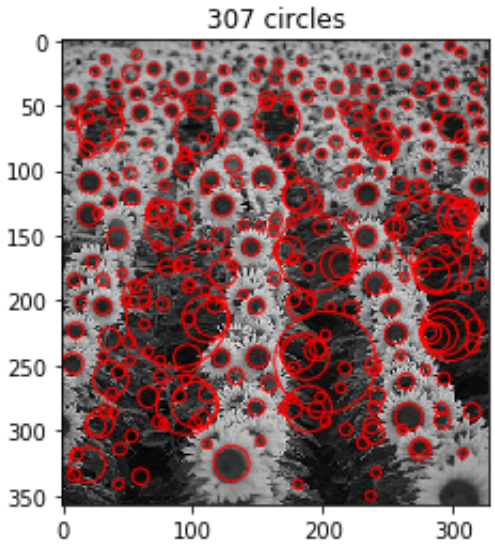
In [12]:
```
# Downsample images
IMG_FOLDER = 'part2_images/'
IMG_NAME = 'einstein.jpg'
out_folder = 'output/'
initial_sigma = 2
num_iter = 15
factor = 1.3
thred = 0.0004
img = read_image(IMG_FOLDER + IMG_NAME)
start_time = time.time()
scale_space ,r  = downsample_image_iteratiion(img,initial_sigma,num_it
er,factor)
position= nonmaximum_suppression(scale_space,thred)
end_time = time.time()
cx = position[1]
cy = position[0]
rad = r[position[2]]
print('Time elapse = ', end_time-start_time)
show_all_circles(img, cx, cy, rad,out_folder+'DownSample_'+IMG_NAME)
```

```
Time elapse =  0.7379341125488281
```



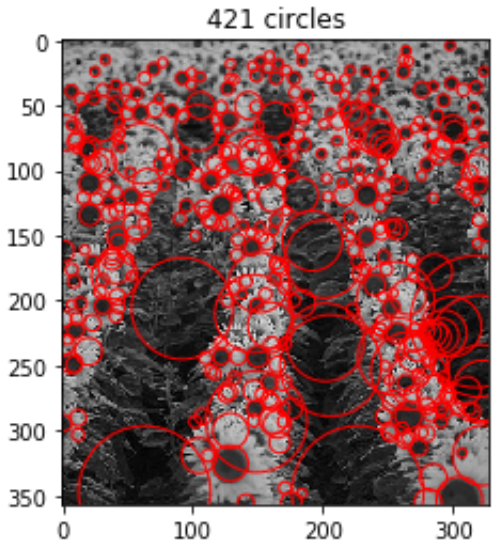
In [13]:
```
# Increase Filter size
IMG_FOLDER = 'part2_images/'
IMG_NAME = 'sunflowers.jpg'
out_folder = 'output/'
initial_sigma = 2
num_iter = 15
factor = 1.3
thred = 0.025
img = read_image(IMG_FOLDER + IMG_NAME)
start_time = time.time()
scale_space ,r  = increase_filter_image_iteratiion(img,initial_sigma,n
um_iter,factor)
position= nonmaximum_suppression(scale_space, thred)
end_time = time.time()
cx = position[1]
cy = position[0]
rad = r[position[2]]
print('Time elapse = ', end_time-start_time)
show_all_circles(img, cx, cy, rad,out_folder+ 'UpSample_'+IMG_NAME)
```

```
Time elapse =  0.8343658447265625
```



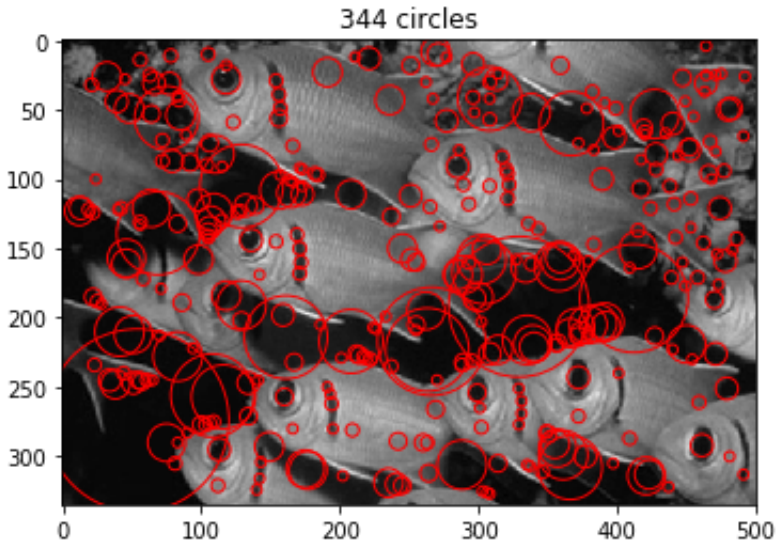
In [17]:
```
# Downsample images
IMG_FOLDER = 'part2_images/'
IMG_NAME = 'sunflowers.jpg'
out_folder = 'output/'
initial_sigma = 2
num_iter = 15
factor = 1.3
thred = 0.0008
img = read_image(IMG_FOLDER + IMG_NAME)
start_time = time.time()
scale_space ,r  = downsample_image_iteratiion(img,initial_sigma,num_it
er,factor)
position= nonmaximum_suppression(scale_space,thred)
end_time = time.time()
cx = position[1]
cy = position[0]
rad = r[position[2]]
print('Time elapse = ', end_time-start_time)
show_all_circles(img, cx, cy, rad,out_folder+'DownSample_'+IMG_NAME)
```

```
Time elapse =  0.2984631061553955
```



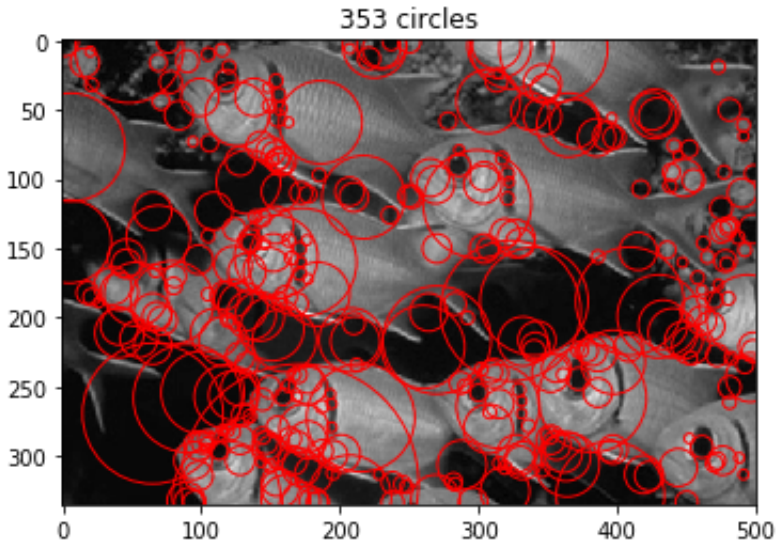
In [18]:
```
# Increase Filter size
IMG_FOLDER = 'part2_images/'
IMG_NAME = 'fishes.jpg'
out_folder = 'output/'
initial_sigma = 2
num_iter = 15
factor = 1.3
thred = 0.025
img = read_image(IMG_FOLDER + IMG_NAME)
start_time = time.time()
scale_space ,r  = increase_filter_image_iteratiion(img,initial_sigma,n
um_iter,factor)
position= nonmaximum_suppression(scale_space, thred)
end_time = time.time()
cx = position[1]
cy = position[0]
rad = r[position[2]]
print('Time elapse = ', end_time-start_time)
show_all_circles(img, cx, cy, rad,out_folder+ 'UpSample_'+IMG_NAME)
```

```
Time elapse =  1.2124390602111816
```



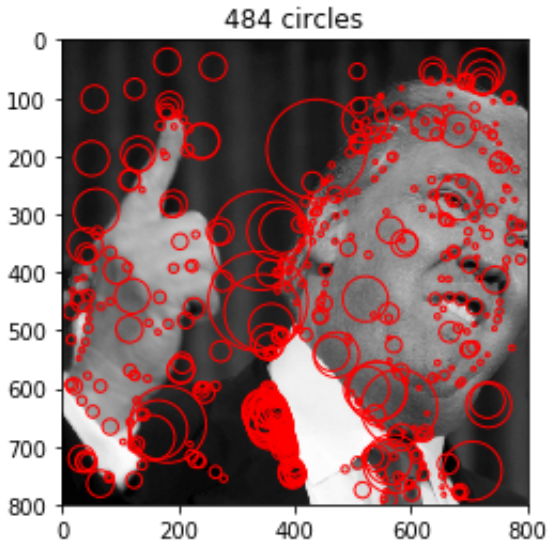
In [20]:
```
# Downsample images
IMG_FOLDER = 'part2_images/'
IMG_NAME = 'fishes.jpg'
out_folder = 'output/'
initial_sigma = 2
num_iter = 15
factor = 1.3
thred = 0.0005
img = read_image(IMG_FOLDER + IMG_NAME)
start_time = time.time()
scale_space ,r  = downsample_image_iteratiion(img,initial_sigma,num_it
er,factor)
position= nonmaximum_suppression(scale_space,thred)
end_time = time.time()
cx = position[1]
cy = position[0]
rad = r[position[2]]
print('Time elapse = ', end_time-start_time)
show_all_circles(img, cx, cy, rad,out_folder+'DownSample_'+IMG_NAME)
```

```
Time elapse =  0.41802000999450684
```



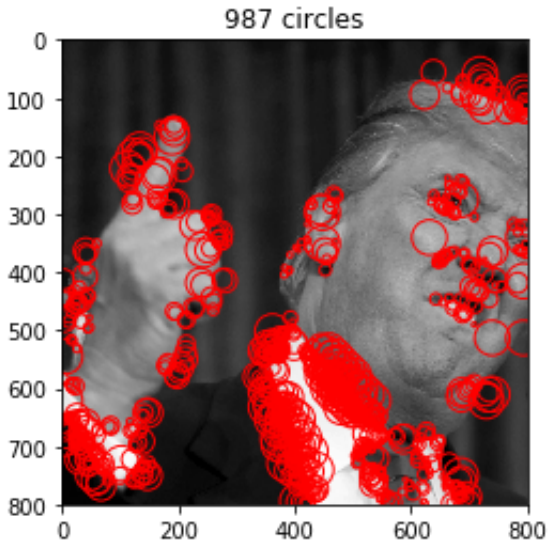
In [37]:
```
# Increase Filter size
IMG_FOLDER = 'part2_images/'
IMG_NAME = 'a1.jpg'
out_folder = 'output/'
initial_sigma = 2
num_iter = 15
factor = 1.3
thred = 0.025
img = read_image(IMG_FOLDER + IMG_NAME)
start_time = time.time()
scale_space ,r  = increase_filter_image_iteratiion(img,initial_sigma,n
um_iter,factor)
position= nonmaximum_suppression(scale_space, thred)
end_time = time.time()
cx = position[1]
cy = position[0]
rad = r[position[2]]
print('Time elapse = ', end_time-start_time)
show_all_circles(img, cx, cy, rad,out_folder+ 'UpSample_'+IMG_NAME)
```

```
Time elapse =  4.31630802154541
```



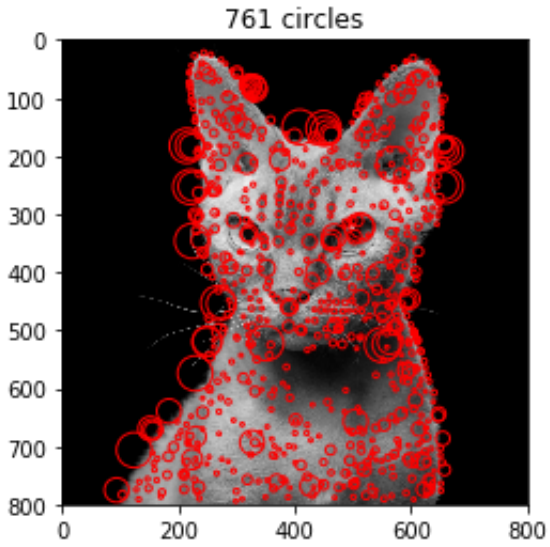
In [44]:
```
# Downsample images
IMG_FOLDER = 'part2_images/'
IMG_NAME = 'a1.jpg'
out_folder = 'output/'
initial_sigma = 2
num_iter = 15
factor = 1.2
thred = 0.0005
img = read_image(IMG_FOLDER + IMG_NAME)
start_time = time.time()
scale_space ,r  = downsample_image_iteratiion(img,initial_sigma,num_it
er,factor)
position= nonmaximum_suppression(scale_space,thred)
end_time = time.time()
cx = position[1]
cy = position[0]
rad = r[position[2]]
print('Time elapse = ', end_time-start_time)
show_all_circles(img, cx, cy, rad,out_folder+'DownSample_'+IMG_NAME)
```

```
Time elapse =  1.2506718635559082
```



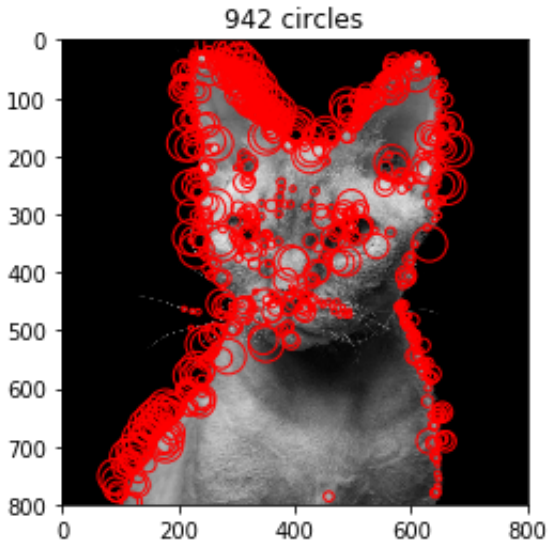
In [47]:
```
# Increase Filter size
IMG_FOLDER = 'part2_images/'
IMG_NAME = 'b1.jpg'
out_folder = 'output/'
initial_sigma = 2
num_iter = 15
factor = 1.2
thred = 0.01
img = read_image(IMG_FOLDER + IMG_NAME)
start_time = time.time()
scale_space ,r  = increase_filter_image_iteratiion(img,initial_sigma,n
um_iter,factor)
position= nonmaximum_suppression(scale_space, thred)
end_time = time.time()
cx = position[1]
cy = position[0]
rad = r[position[2]]
print('Time elapse = ', end_time-start_time)
show_all_circles(img, cx, cy, rad,out_folder+ 'UpSample_'+IMG_NAME)
```

```
Time elapse =  2.3197691440582275
```



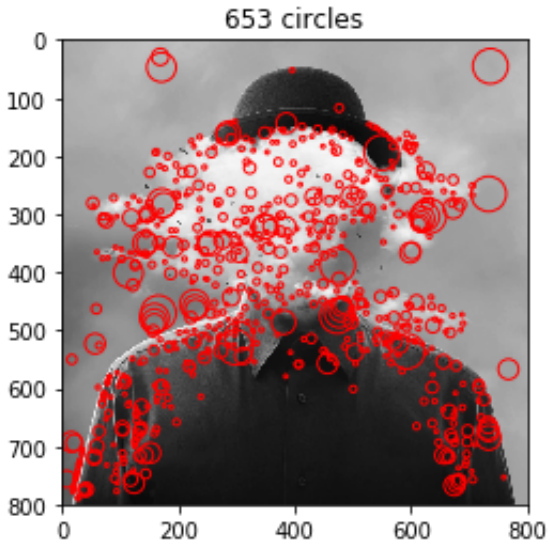
In [50]:
```
# Downsample images
IMG_FOLDER = 'part2_images/'
IMG_NAME = 'b1.jpg'
out_folder = 'output/'
initial_sigma = 2
num_iter = 15
factor = 1.2
thred = 0.0005
img = read_image(IMG_FOLDER + IMG_NAME)
start_time = time.time()
scale_space ,r  = downsample_image_iteratiion(img,initial_sigma,num_it
er,factor)
position= nonmaximum_suppression(scale_space,thred)
end_time = time.time()
cx = position[1]
cy = position[0]
rad = r[position[2]]
print('Time elapse = ', end_time-start_time)
show_all_circles(img, cx, cy, rad,out_folder+'DownSample_'+IMG_NAME)
```

```
Time elapse =  1.3327178955078125
```



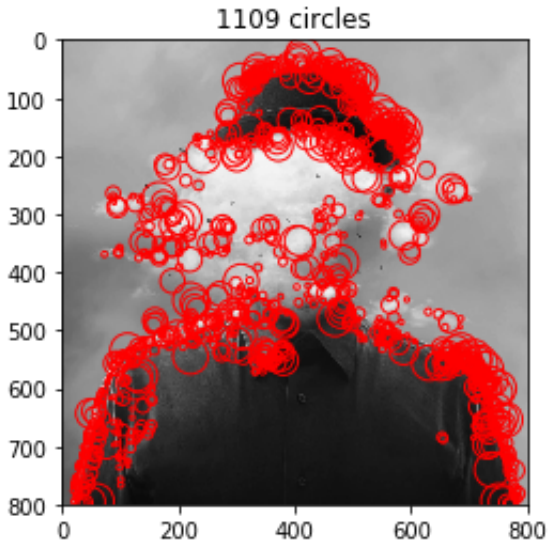
In [55]:
```
# Increase Filter size
IMG_FOLDER = 'part2_images/'
IMG_NAME = 'c1.jpg'
out_folder = 'output/'
initial_sigma = 2
num_iter = 15
factor = 1.2
thred = 0.01
img = read_image(IMG_FOLDER + IMG_NAME)
start_time = time.time()
scale_space ,r  = increase_filter_image_iteratiion(img,initial_sigma,n
um_iter,factor)
position= nonmaximum_suppression(scale_space, thred)
end_time = time.time()
cx = position[1]
cy = position[0]
rad = r[position[2]]
print('Time elapse = ', end_time-start_time)
show_all_circles(img, cx, cy, rad,out_folder+ 'UpSample_'+IMG_NAME)
```

```
Time elapse =  2.118086814880371
```



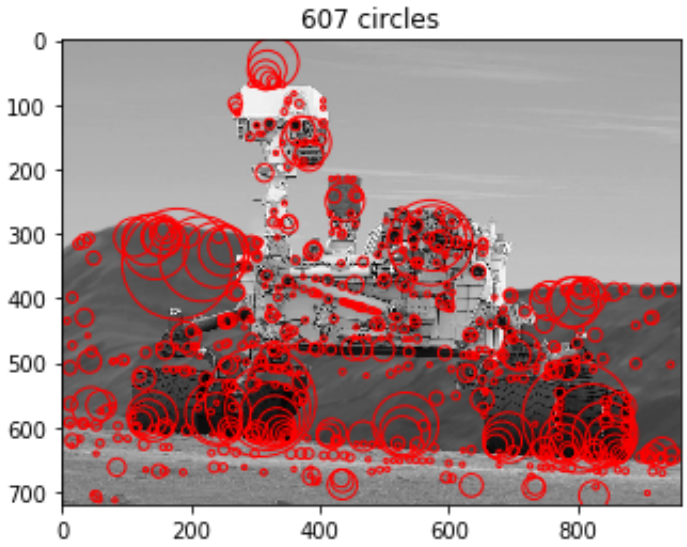
In [59]:
```
# Downsample images
IMG_FOLDER = 'part2_images/'
IMG_NAME = 'c1.jpg'
out_folder = 'output/'
initial_sigma = 2
num_iter = 15
factor = 1.2
thred = 0.0001
img = read_image(IMG_FOLDER + IMG_NAME)
start_time = time.time()
scale_space ,r  = downsample_image_iteratiion(img,initial_sigma,num_it
er,factor)
position= nonmaximum_suppression(scale_space,thred)
end_time = time.time()
cx = position[1]
cy = position[0]
rad = r[position[2]]
print('Time elapse = ', end_time-start_time)
show_all_circles(img, cx, cy, rad,out_folder+'DownSample_'+IMG_NAME)
```

```
Time elapse =  1.1998817920684814
```



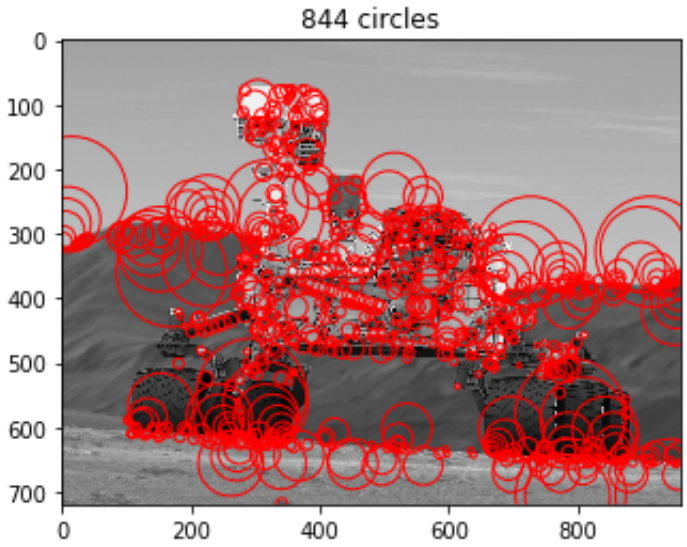
In [261]:
```
# Increase Filter size
IMG_FOLDER = 'part2_images/'
IMG_NAME = 'd1.jpg'
out_folder = 'output/'
initial_sigma = 2
num_iter = 15
factor = 1.3
thred = 0.025
img = read_image(IMG_FOLDER + IMG_NAME)
start_time = time.time()
scale_space ,r  = increase_filter_image_iteratiion(img,initial_sigma,n
um_iter,factor)
position= nonmaximum_suppression(scale_space, thred)
end_time = time.time()
cx = position[1]
cy = position[0]
rad = r[position[2]]
print('Time elapse = ', end_time-start_time)
show_all_circles(img, cx, cy, rad,out_folder+ 'UpSample_'+IMG_NAME)
```

```
Time elapse =  4.744199752807617
```



In [61]:
```
# Downsample images
IMG_FOLDER = 'part2_images/'
IMG_NAME = 'd1.jpg'
out_folder = 'output/'
initial_sigma = 2
num_iter = 15
factor = 1.3
thred = 0.0005
img = read_image(IMG_FOLDER + IMG_NAME)
start_time = time.time()
scale_space ,r  = downsample_image_iteratiion(img,initial_sigma,num_it
er,factor)
position= nonmaximum_suppression(scale_space,thred)
end_time = time.time()
cx = position[1]
cy = position[0]
rad = r[position[2]]
print('Time elapse = ', end_time-start_time)
show_all_circles(img, cx, cy, rad,out_folder+'DownSample_'+IMG_NAME)
```

```
Time elapse =  1.5782489776611328
```



In [ ]: