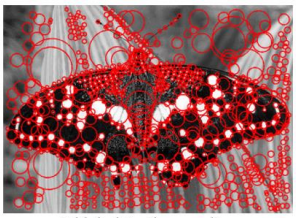
Introduction

As illustrated by the below two images, the objective of this project is to implement a Laplacian blob detector.

An input image



A blob detection result

Design

Algorithm outline:

• Generate a Laplacian of Gaussian filter: Use MATLAB built-in function “fspecial” to generate LoG filter.

• Build a Laplacian scale space, starting with some initial scale and going for n iterations:

- Filter image with scale-normalized Laplacian at current scale.
  Use my convolution to filter image with scale-normalized Laplacian. The scale space is image’s width multuply length.
- Save square of Laplacian response for current level of scale space.
- Increase scale by a factor k.
  Set sigma = 2 and k = 1.28 as default. LoG scales is the former scale multiply by k. Set the iteration n = 15 as default.

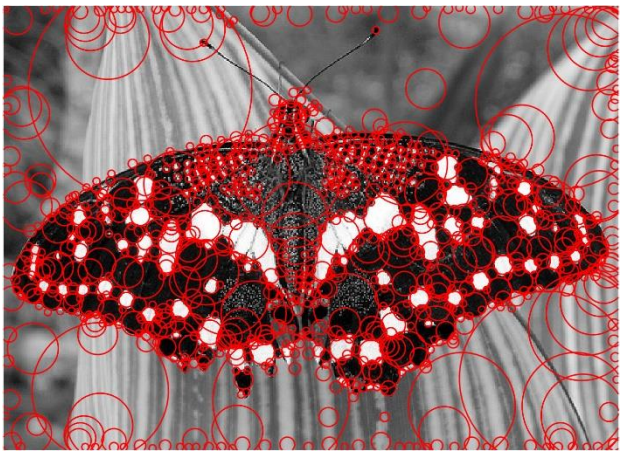
• Perform non-maximum suppression in scale space.

- Correlate image with box filter to find maximum around neighbors for each layer.
- Concatenate each layer as a 3D scale space.
- Finding maximum values in the 3D Scale Space.
- Replacing all non maximum values with zeros.
- Set the threshold = 0.007 as default.

• Display resulting circles at their characteristic scales: Finding coordinates of the maxima and drawing circles for that maxima. The scale of circles is as large as the increasing of LoG scales.

Results

1. butterfly

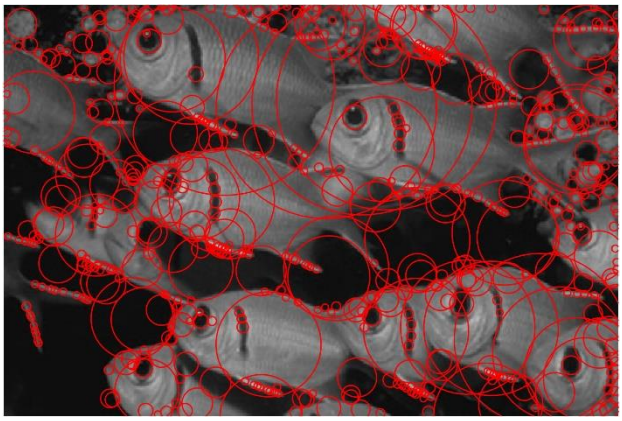


Elapsed time is 415.988502 seconds

2. Einstein

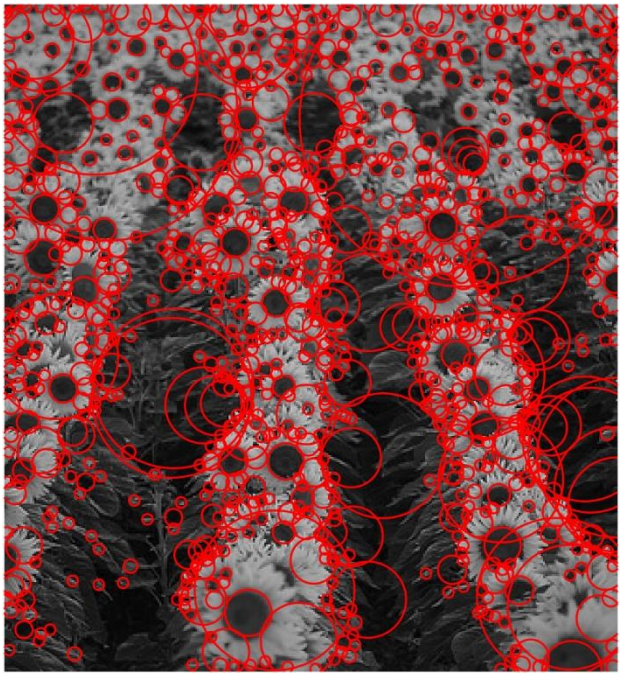
Elapsed time is 892.766778 seconds

3. fishes



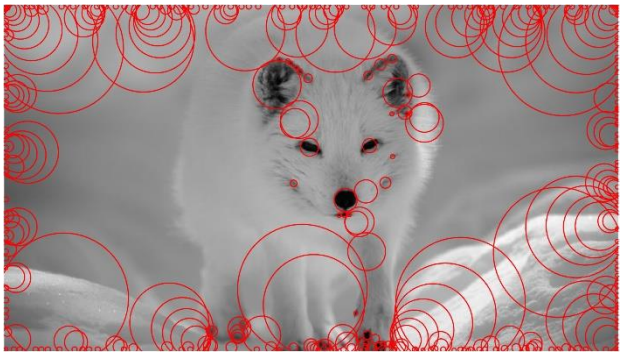
Elapsed time is 297.674474 seconds

4. sunflowers



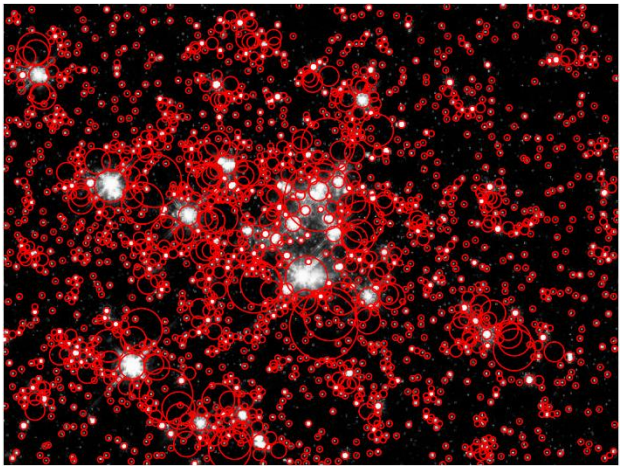
Elapsed time is 293.888381 seconds

5. fox



Elapsed time is 693.421869 seconds

6. stars

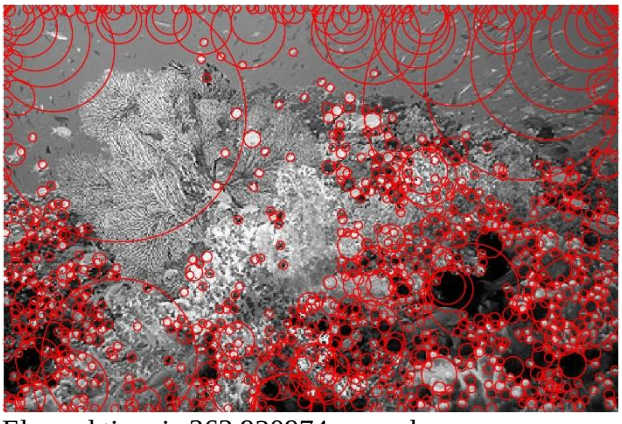


Elapsed time is 713.438301 seconds

7. cat

Elapsed time is 663.342114 seconds

8. coral

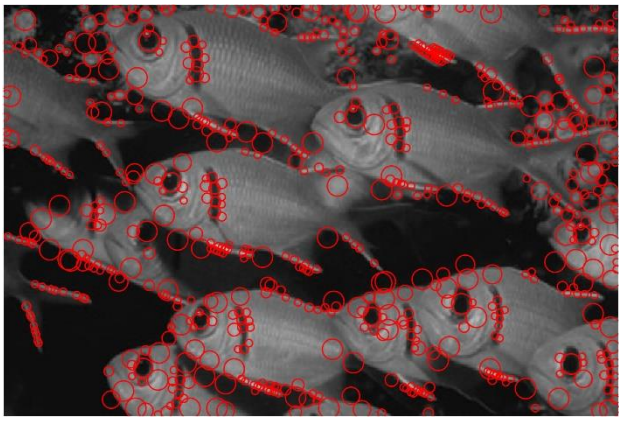


Elapsed time is 363.920974 seconds

Compare

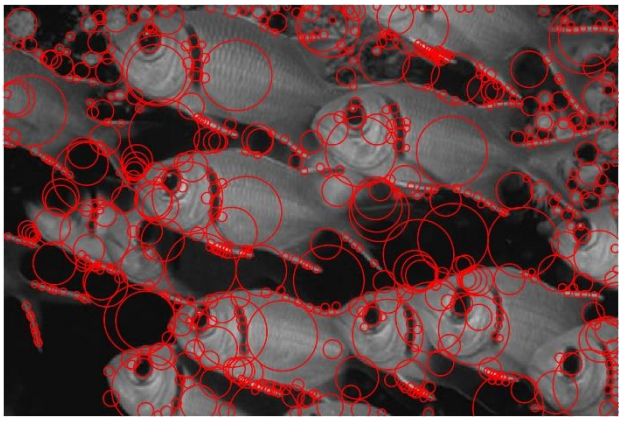
1. Different range of scales (change k)

a. k = 1.08



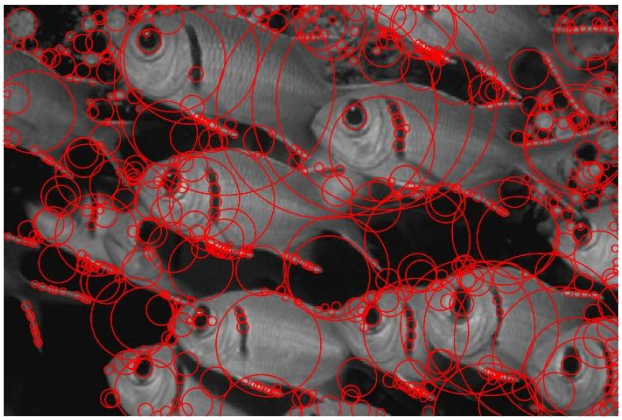
Elapsed time is 11.709121 seconds

b. k = 1.18



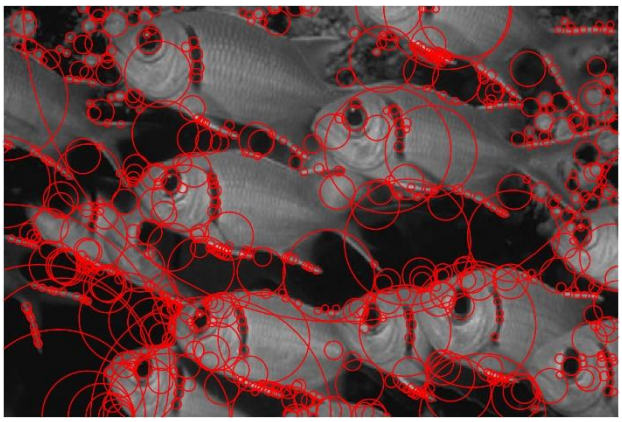
Elapsed time is 118.935763 seconds.

c. k = 1.28



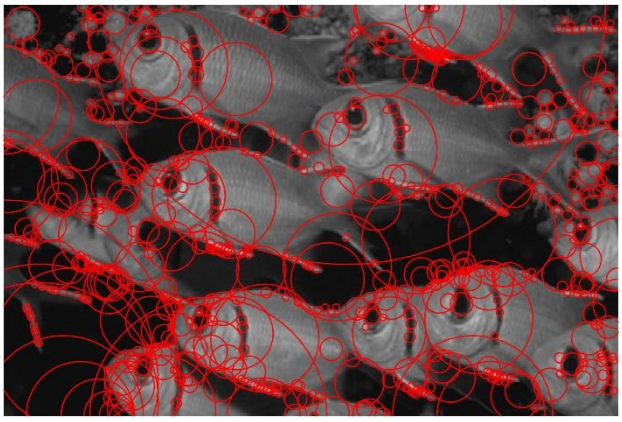
Elapsed time is 297.674474 seconds

d. k = 1.38



Elapsed time is 937.886054 seconds.

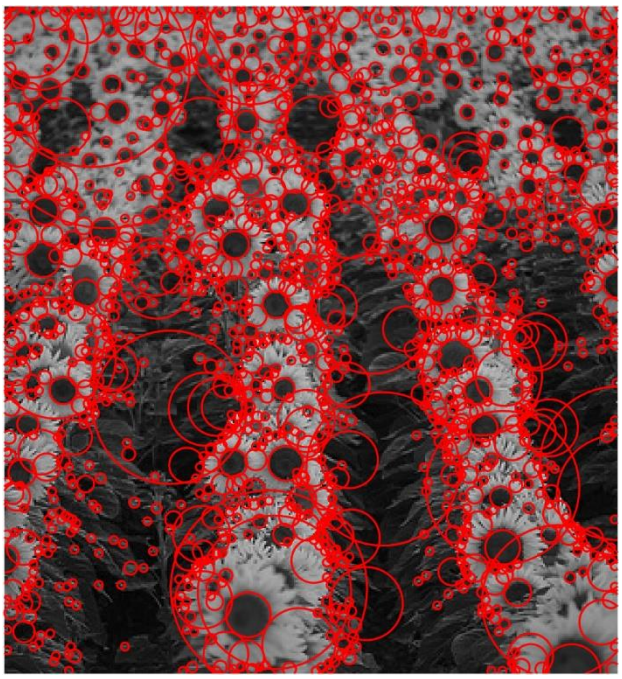
e. k = 1.48



Elapsed time is 3208.578695 seconds.

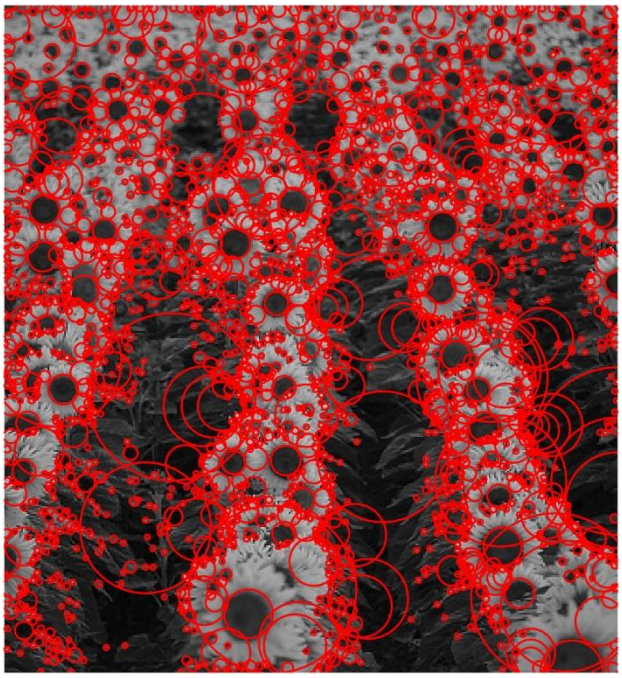
2. Different range of scales (change sigma)

a. sigma = 1



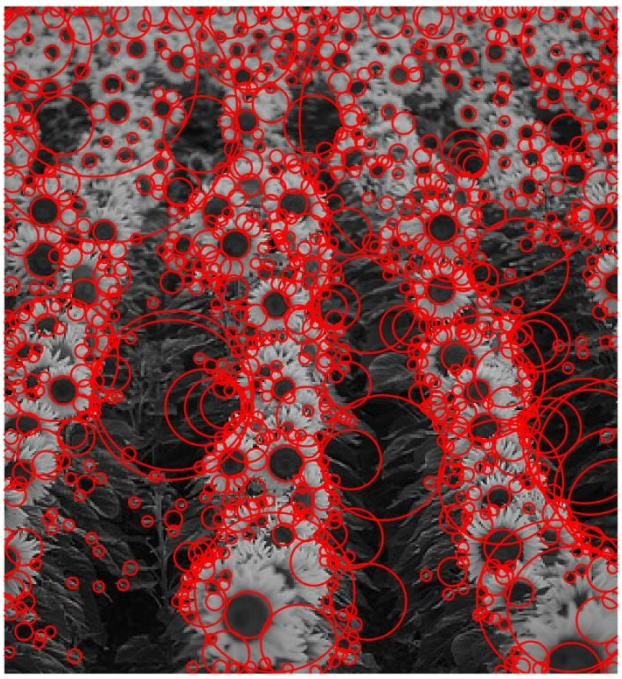
Elapsed time is 88.492995 seconds.

b. sigma = 1.5



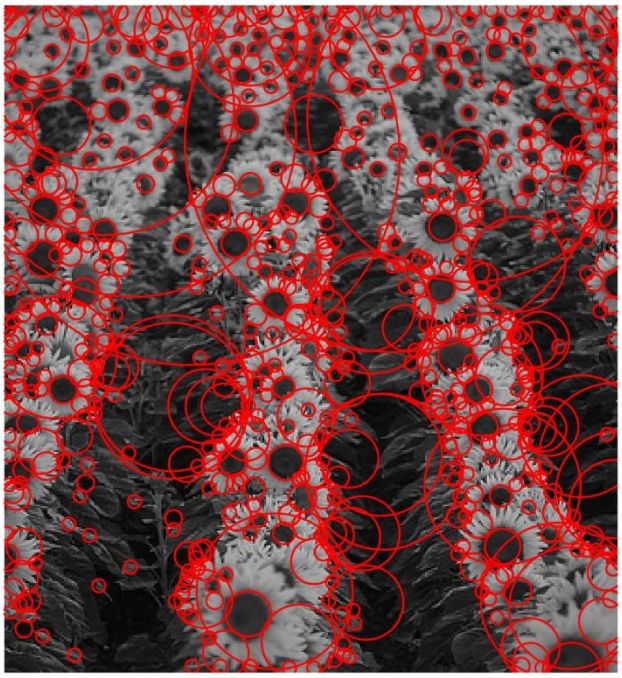
Elapsed time is 184.558745 seconds.

c. sigma = 2



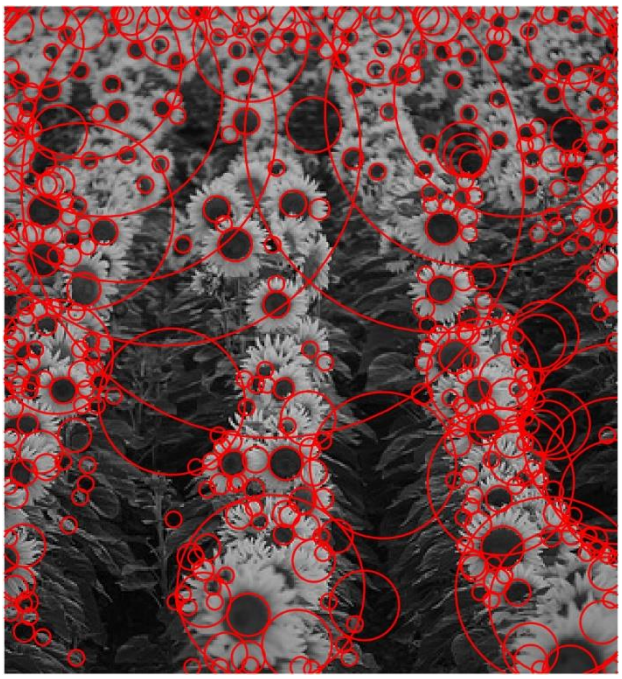
Elapsed time is 293.888381 seconds.

d. sigma = 2.5



Elapsed time is 514.836649 seconds.

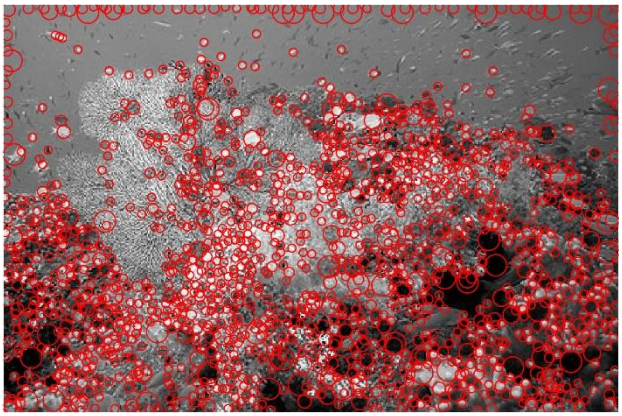
e. sigma = 3



Elapsed time is 866.375548 seconds.

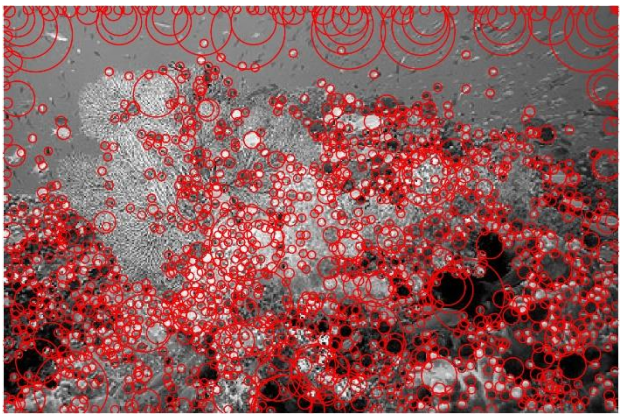
3. Different number of scale spaces(iterations)

a. n = 5



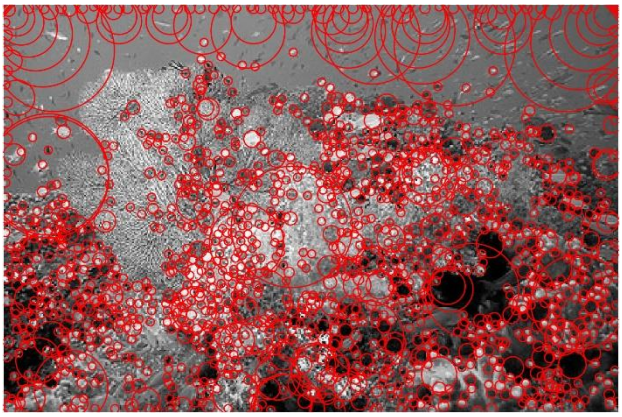
Elapsed time is 3.103118 seconds.

b. n = 10



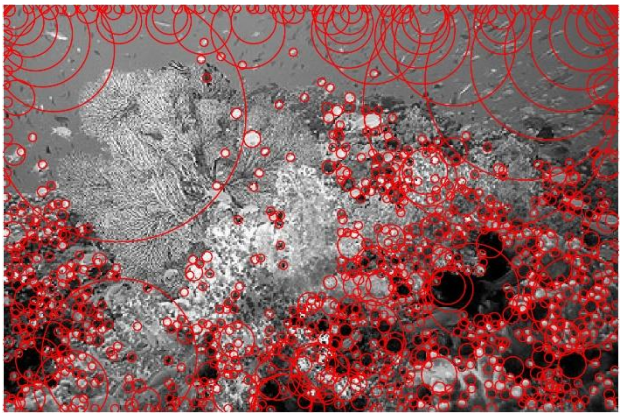
Elapsed time is 26.506491 seconds.

c. n = 12



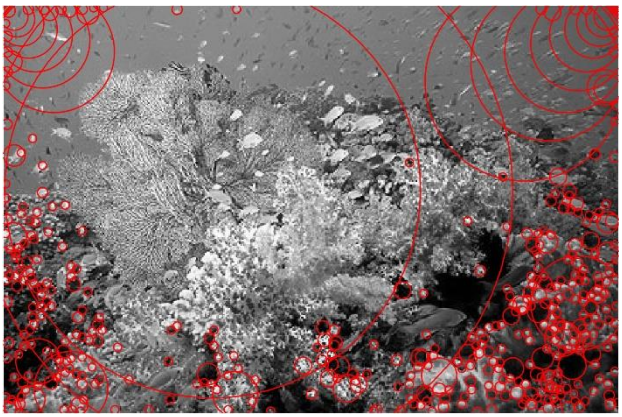
Elapsed time is 53.531793 seconds.

d. n = 15



Elapsed time is 363.920974 seconds.

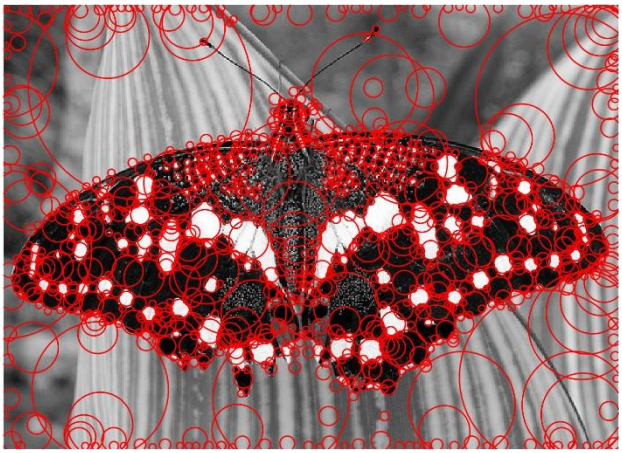
e. n =20



Elapsed time is 8248.871980 seconds.

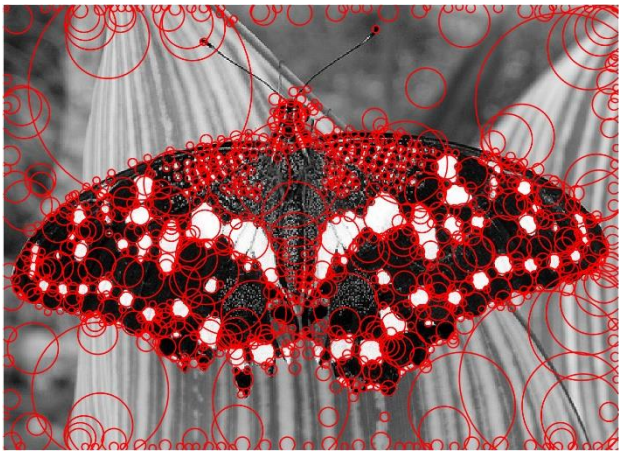
4. Different threshold

a. threshold = 0.0001



Elapsed time is 301.671456 seconds.

b. threshold = 0.007



Elapsed time is 415.988502 seconds

c. threshold = 0.035

Elapsed time is 402.749002 seconds.

d. threshold = 0.082

Elapsed time is 316.006338 seconds.

e. threshold = 0.17

Elapsed time is 298.764881 seconds.

Conclusion

1. Larger sigma detects significant features. Smaller sigma detects fine features.
2. As the range of scale and iterations increase, the lapsed time increases.
3. As the threshold increases, the result displays more significant features.
4. The choice of each variation depends on desired behavior.

Reference

Textbook

https://www.di.ens.fr/willow/teaching/recvis10/assignment1/

https://www.di.ens.fr/willow/teaching/recvis10/assignment1/show_all_circles.m