Devon Quaternik

Table of Contents

ELEN 644 HW 4

Problem 2

```
% Initialize images
im(:,:,1) = imread('cameraman.tif');
im(:,:,2) = imread('rice.png');  % Could not find lighthouse.jpg, used
 rice.png as a substitute.
im(:,:,3) = imread('5.1.09.tiff');
[n, m, nim] = size(im);

% Nubmer of levels to use
lev = 3;

% Initialize filters
h1 = 1; % Effectively the same as not filtering. Average over 1 point.
h2 = .25*[1 2 1];
h3 = (1/16)*[1 4 6 4 1];
h4 = fspecial('gaussian',7,1.0);
h5 = firpm(8,[0.0, 0.4, 0.6, 1.0],[1.0, 1.0, 0.0, 0.0]);
nf = 5;

dow1(:,:,:,1) = dscale2(im(:,:,1),h1,lev);
dow1(:,:,:,2) = dscale2(im(:,:,1),h2,lev);
dow1(:,:,:,3) = dscale2(im(:,:,1),h3,lev);
dow1(:,:,:,4) = dscale2(im(:,:,1),h4,lev);
dow1(:,:,:,5) = dscale2(im(:,:,1),h5,lev);

dow2(:,:,:,1) = dscale2(im(:,:,2),h1,lev);
dow2(:,:,:,2) = dscale2(im(:,:,2),h2,lev);
dow2(:,:,:,3) = dscale2(im(:,:,2),h3,lev);
dow2(:,:,:,4) = dscale2(im(:,:,2),h4,lev);
dow2(:,:,:,5) = dscale2(im(:,:,2),h5,lev);

dow3(:,:,:,1) = dscale2(im(:,:,3),h1,lev);
dow3(:,:,:,2) = dscale2(im(:,:,3),h2,lev);
dow3(:,:,:,3) = dscale2(im(:,:,3),h3,lev);
dow3(:,:,:,4) = dscale2(im(:,:,3),h4,lev);
dow3(:,:,:,5) = dscale2(im(:,:,3),h5,lev);

[m, n, p, q] = size(dow1);
```

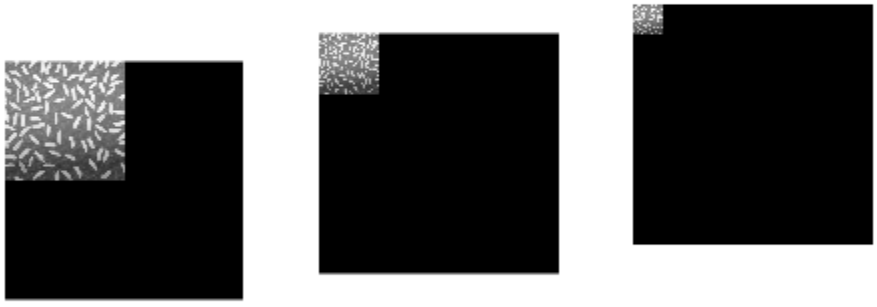
```
% Display levels 1, 2, 3
count = 0;
for j = 0:nf-1
    for i = 1:lev
        str2 = sprintf('Downscale Filter # %d',j+1);
        figure(3*j+1);
        subplot(1,lev,i),imshow(dow1(:,:,i,j+1),[]);
        suptitle(str2);
        figure(3*j+2);
        subplot(1,lev,i),imshow(dow2(:,:,i,j+1),[]);
        suptitle(str2);
        figure(3*j+3);
        subplot(1,lev,i),imshow(dow3(:,:,i,j+1),[]);
        suptitle(str2);
    end
    count = count+1;
end

disp('Zero padding used to unify image size and allow for certain data
 structures.');
disp('Downscaling, it is difficult to tell eexactly which filters work
 best. Although 2 and 3 appear slightly more clear than the rest, none
 are particularly bad.');
```

```
Zero padding used to unify image size and allow for certain data
 structures.
Downscaling, it is difficult to tell eexactly which filters work best.
 Although 2 and 3 appear slightly more clear than the rest, none are
 particularly bad.
```

Downscale Filter # 1

Downscale Filter # 1



Downscale Filter # 1

Downscale Filter # 2

Downscale Filter # 2

Downscale Filter # 2

Downscale Filter # 3

Downscale Filter # 3

Downscale Filter # 3

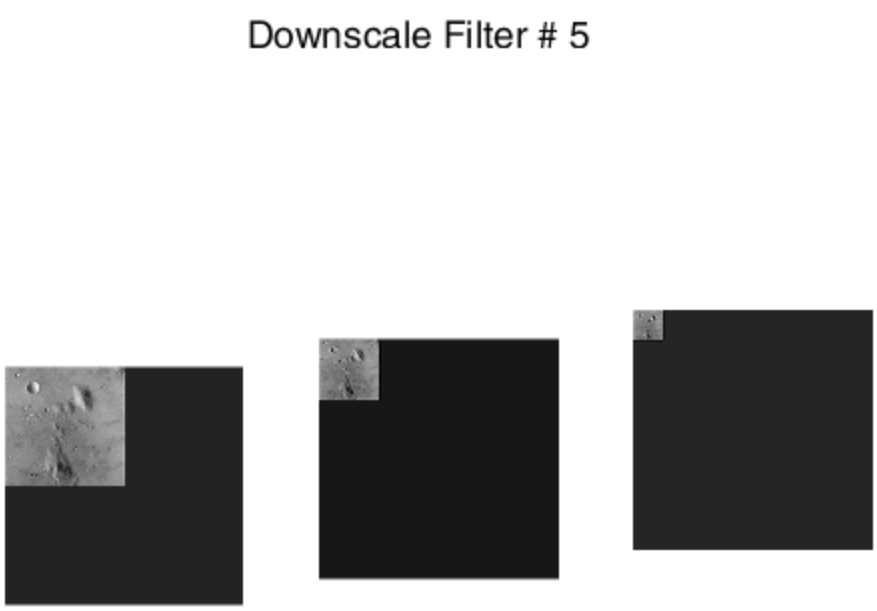
Downscale Filter # 4

Downscale Filter # 4

Downscale Filter # 4

Downscale Filter # 5

Downscale Filter # 5



Problem 2

```
up1(:,:,:,1) = uscale2(dow1(:,:,:,1),h1,lev);
up1(:,:,:,2) = uscale2(dow1(:,:,:,2),h2,lev);
up1(:,:,:,3) = uscale2(dow1(:,:,:,3),h3,lev);
up1(:,:,:,4) = uscale2(dow1(:,:,:,4),h4,lev);
up1(:,:,:,5) = uscale2(dow1(:,:,:,5),h5,lev);

up2(:,:,:,1) = uscale2(dow2(:,:,:,1),h1,lev);
up2(:,:,:,2) = uscale2(dow2(:,:,:,2),h2,lev);
up2(:,:,:,3) = uscale2(dow2(:,:,:,3),h3,lev);
up2(:,:,:,4) = uscale2(dow2(:,:,:,4),h4,lev);
up2(:,:,:,5) = uscale2(dow2(:,:,:,5),h5,lev);

up3(:,:,:,1) = uscale2(dow3(:,:,:,1),h1,lev);
up3(:,:,:,2) = uscale2(dow3(:,:,:,2),h2,lev);
up3(:,:,:,3) = uscale2(dow3(:,:,:,3),h3,lev);
up3(:,:,:,4) = uscale2(dow3(:,:,:,4),h4,lev);
up3(:,:,:,5) = uscale2(dow3(:,:,:,5),h5,lev);

% Display estimated levels 0, 1, 2

for j = 0:nf-1
    for i = 1:lev
        str2 = sprintf('Upscale Filter # %d',j+1);
```

```
        figure(3*(j+count)+1);
        subplot(1,lev,i),imshow(up1(:,:,i,j+1),[]);
        suptitle(str2);
        figure(3*(j+count)+2);
        subplot(1,lev,i),imshow(up2(:,:,i,j+1),[]);
        suptitle(str2);
        figure(3*(j+count)+3);
        subplot(1,lev,i),imshow(up3(:,:,i,j+1),[]);
        suptitle(str2);
    end
end

% Create residual images

for j = 0:nf-1
    for i = 1:lev
        if i == 1
            res1(:,:,i,j+1) = double(im(:,:,1)) - double(up1(:,:,1,j
+1));
            res2(:,:,i,j+1) = double(im(:,:,2)) - double(up2(:,:,1,j
+1));
            res3(:,:,i,j+1) = double(im(:,:,3)) - double(up3(:,:,1,j
+1));
        else
            res1(:,:,i,j+1) = dow1(:,:,i-1,j+1) - up1(:,:,i,j+1);
            res2(:,:,i,j+1) = dow2(:,:,i-1,j+1) - up2(:,:,i,j+1);
            res3(:,:,i,j+1) = dow3(:,:,i-1,j+1) - up3(:,:,i,j+1);
        end
        ms1(i,j+1) = meansqr(res1(:,:,i,j+1));
        ms2(i,j+1) = meansqr(res2(:,:,i,j+1));
        ms3(i,j+1) = meansqr(res3(:,:,i,j+1));

        str1 = sprintf('MSE Residual Image 1, Filter # %d Level %d:
 %d',j+1,i-1,ms1(i,j+1));
        disp(str1);
        str1 = sprintf('MSE Residual Image 2, Filter # %d Level %d:
 %d',j+1,i-1,ms2(i,j+1));
        disp(str1);
        str1 = sprintf('MSE Residual Image 3, Filter # %d Level %d:
 %d',j+1,i-1,ms3(i,j+1));
        disp(str1);

        str2 = sprintf('Image 1 Filter # %d Residual',j+1);
        str3 = sprintf('Level %d',i-1);
        figure(6*(j+count)+1);
        subplot(1,lev,i),imshow(res1(:,:,i,j+1),[]);
        suptitle(str2);
        figure(6*(j+count)+2);
        subplot(1,lev,i), histogram(res1(:,:,i,j+1));
        title(str3);
        suptitle(str2);

        str2 = sprintf('Image 2 Filter # %d Residual',j+1);
        figure(6*(j+count)+3);
```

```
        subplot(1,lev,i),imshow(res2(:,:,i,j+1),[]);
        suptitle(str2);
        figure(6*(j+count)+4);
        subplot(1,lev,i), histogram(res2(:,:,i,j+1));
        title(str3);
        suptitle(str2);

        str2 = sprintf('Image 3 Filter # %d Residual',j+1);
        figure(6*(j+count)+5);
        subplot(1,lev,i),imshow(res3(:,:,i,j+1),[]);
        suptitle(str2);
        figure(6*(j+count)+6);
        subplot(1,lev,i), histogram(res3(:,:,i,j+1));
        title(str3);
        suptitle(str2);

    end
end
disp('No filter is useless for upscaling, making it bad choice for
 pyramid making.');
disp('Filter 2 works well and the interpolated image looks correct.
 You can easily see the edges on the residual at any level.');
disp('Filter 3 is similar to 2, but appears to be slightly worse
 overall. Again you can see images at any level.');
disp('Filters 4 and 5 both have noticeable banding across both.
 Neither are particularly suited to this application and the results
 are poor, if still visible');
disp('Order from best to worst is filter 2,3,4,5,1');
```

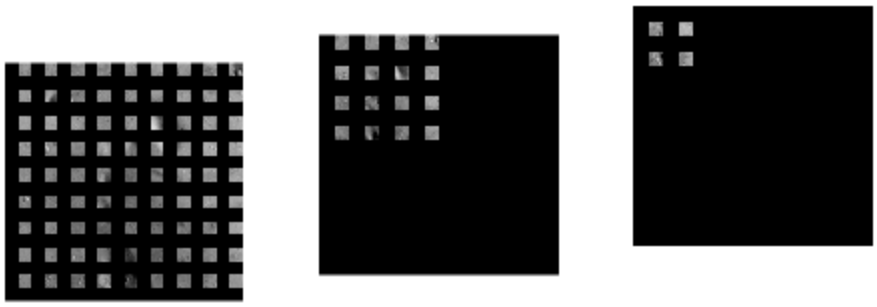
```
MSE Residual Image 1, Filter # 1 Level 0: 1.798193e+04
MSE Residual Image 2, Filter # 1 Level 0: 1.418152e+04
MSE Residual Image 3, Filter # 1 Level 0: 1.709191e+04
MSE Residual Image 1, Filter # 1 Level 1: 4.488263e+03
MSE Residual Image 2, Filter # 1 Level 1: 3.549687e+03
MSE Residual Image 3, Filter # 1 Level 1: 4.274314e+03
MSE Residual Image 1, Filter # 1 Level 2: 1.131877e+03
MSE Residual Image 2, Filter # 1 Level 2: 8.933270e+02
MSE Residual Image 3, Filter # 1 Level 2: 1.069524e+03
MSE Residual Image 1, Filter # 2 Level 0: 4.758880e+03
MSE Residual Image 2, Filter # 2 Level 0: 3.697415e+03
MSE Residual Image 3, Filter # 2 Level 0: 4.399677e+03
MSE Residual Image 1, Filter # 2 Level 1: 1.172520e+03
MSE Residual Image 2, Filter # 2 Level 1: 9.278472e+02
MSE Residual Image 3, Filter # 2 Level 1: 1.094569e+03
MSE Residual Image 1, Filter # 2 Level 2: 2.925246e+02
MSE Residual Image 2, Filter # 2 Level 2: 2.358596e+02
MSE Residual Image 3, Filter # 2 Level 2: 2.747317e+02
MSE Residual Image 1, Filter # 3 Level 0: 4.867461e+03
MSE Residual Image 2, Filter # 3 Level 0: 3.773645e+03
MSE Residual Image 3, Filter # 3 Level 0: 4.452162e+03
MSE Residual Image 1, Filter # 3 Level 1: 1.178530e+03
MSE Residual Image 2, Filter # 3 Level 1: 9.411225e+02
MSE Residual Image 3, Filter # 3 Level 1: 1.100716e+03
MSE Residual Image 1, Filter # 3 Level 2: 2.937034e+02
```

```
MSE Residual Image 2, Filter # 3 Level 2: 2.342697e+02
MSE Residual Image 3, Filter # 3 Level 2: 2.760655e+02
MSE Residual Image 1, Filter # 4 Level 0: 4.862683e+03
MSE Residual Image 2, Filter # 4 Level 0: 3.771003e+03
MSE Residual Image 3, Filter # 4 Level 0: 4.450017e+03
MSE Residual Image 1, Filter # 4 Level 1: 1.179326e+03
MSE Residual Image 2, Filter # 4 Level 1: 9.412443e+02
MSE Residual Image 3, Filter # 4 Level 1: 1.101406e+03
MSE Residual Image 1, Filter # 4 Level 2: 2.939331e+02
MSE Residual Image 2, Filter # 4 Level 2: 2.344315e+02
MSE Residual Image 3, Filter # 4 Level 2: 2.763500e+02
MSE Residual Image 1, Filter # 5 Level 0: 8.559735e+03
MSE Residual Image 2, Filter # 5 Level 0: 6.708571e+03
MSE Residual Image 3, Filter # 5 Level 0: 8.177129e+03
MSE Residual Image 1, Filter # 5 Level 1: 1.338921e+03
MSE Residual Image 2, Filter # 5 Level 1: 1.040605e+03
MSE Residual Image 3, Filter # 5 Level 1: 1.267818e+03
MSE Residual Image 1, Filter # 5 Level 2: 2.106971e+02
MSE Residual Image 2, Filter # 5 Level 2: 1.739011e+02
MSE Residual Image 3, Filter # 5 Level 2: 1.966051e+02
No filter is useless for upscaling, making it bad choice for pyramid
 making.
Filter 2 works well and the interpolated image looks correct. You can
 easily see the edges on the residual at any level.
Filter 3 is similar to 2, but appears to be slightly worse overall.
 Again you can see images at any level.
Filters 4 and 5 both have noticeable banding across both. Neither are
 particularly suited to this application and the results are poor, if
 still visible
Order from best to worst is filter 2,3,4,5,1
```

Upscale Filter # 1

Upscale Filter # 1

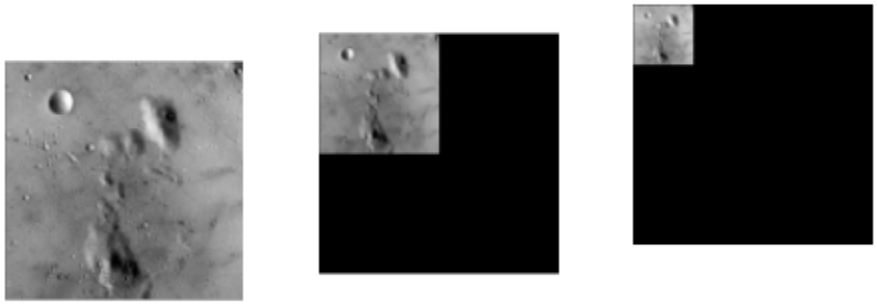
Upscale Filter # 1



Upscale Filter # 2

Upscale Filter # 2

Upscale Filter # 2



Upscale Filter # 3

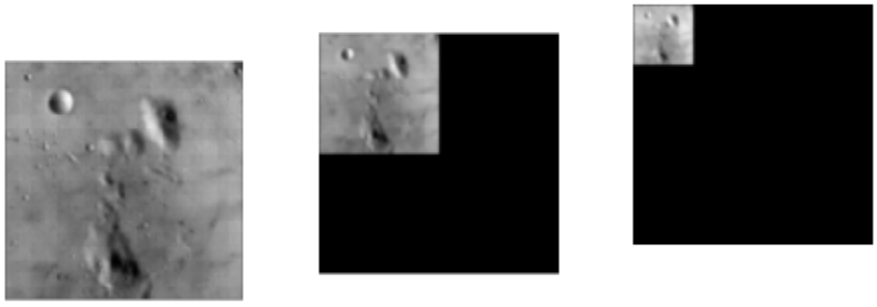
Upscale Filter # 3

Upscale Filter # 3

Upscale Filter # 4

Upscale Filter # 4

Upscale Filter # 4



Upscale Filter # 5

Upscale Filter # 5

Upscale Filter # 5

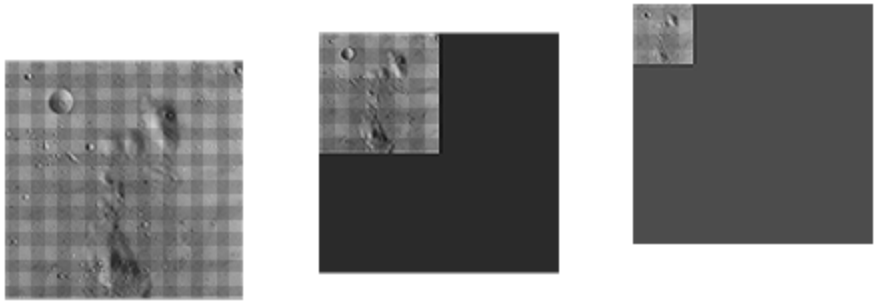


Image 1 Filter # 1 Residual

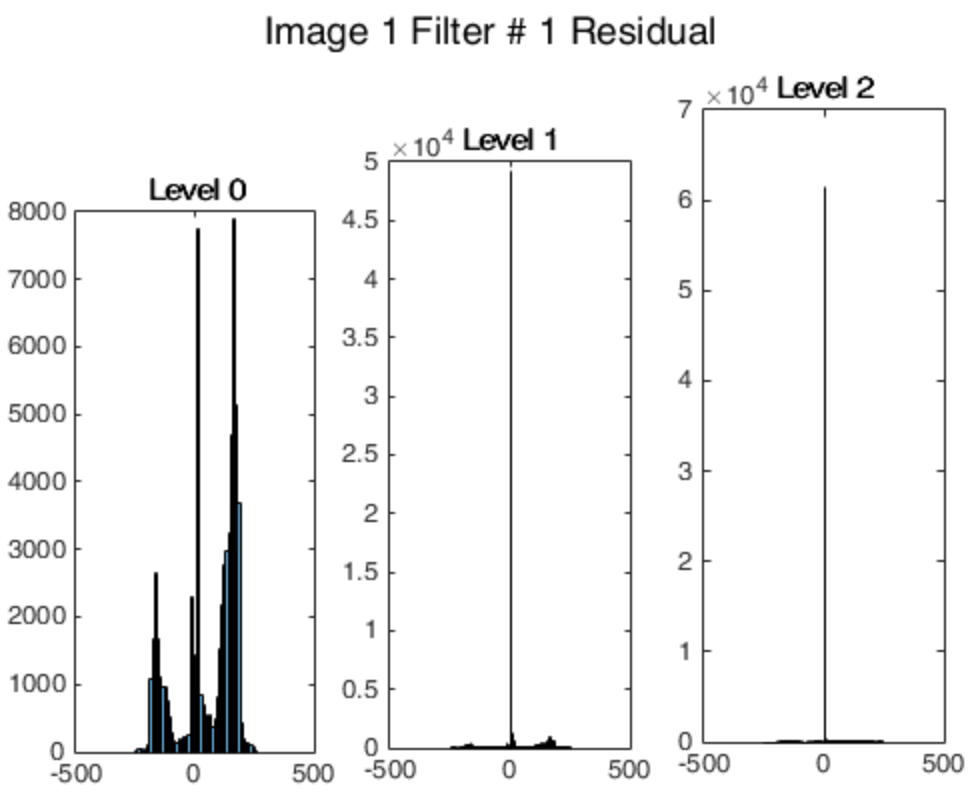


Image 1 Filter # 1 Residual
Level 0
Level 1
Level 2
×10^4
8000
7000
6000
5000
4000
3000
2000
1000
0
4.5
3.5
2.5
1.5
0.5
-500
0
500

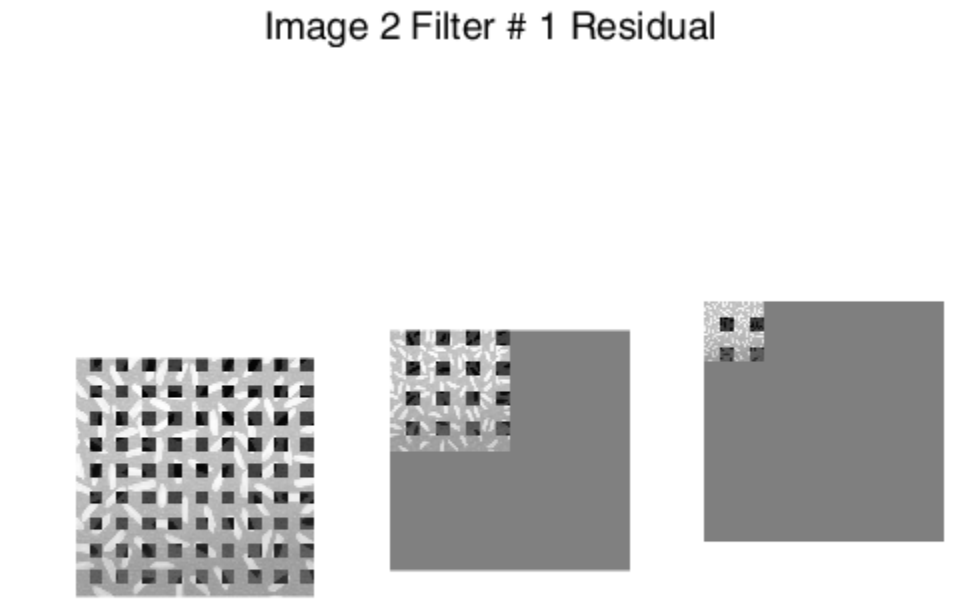


Image 2 Filter # 1 Residual

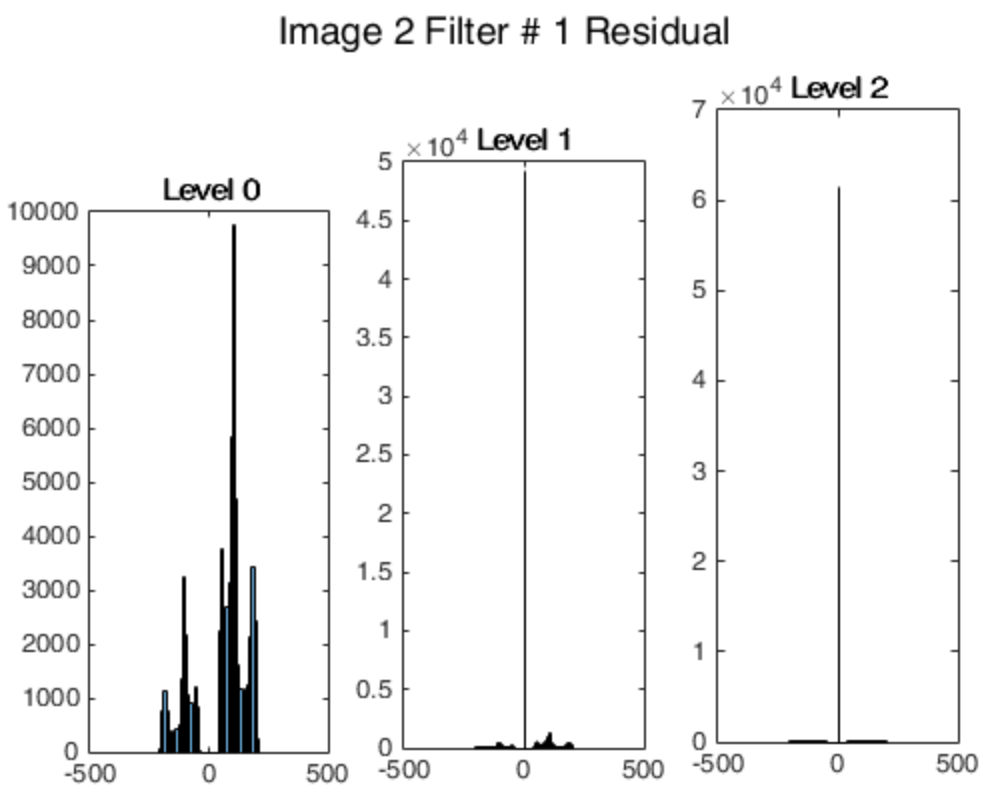


Image 2 Filter # 1 Residual
Level 0
Level 1
Level 2
×10^4
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-500
0
500
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
7
6
5
4
3
2
1

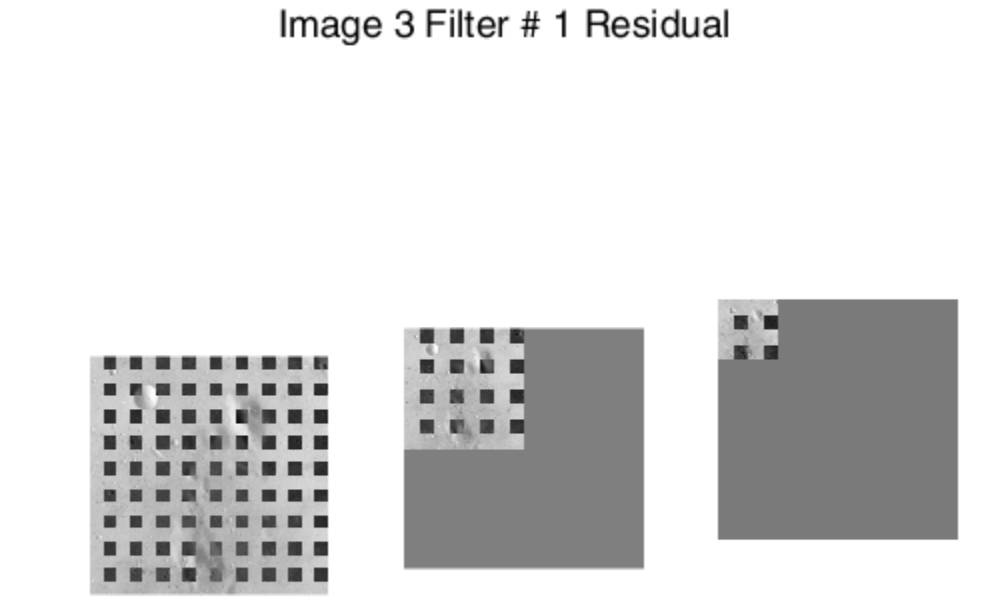


Image 3 Filter # 1 Residual

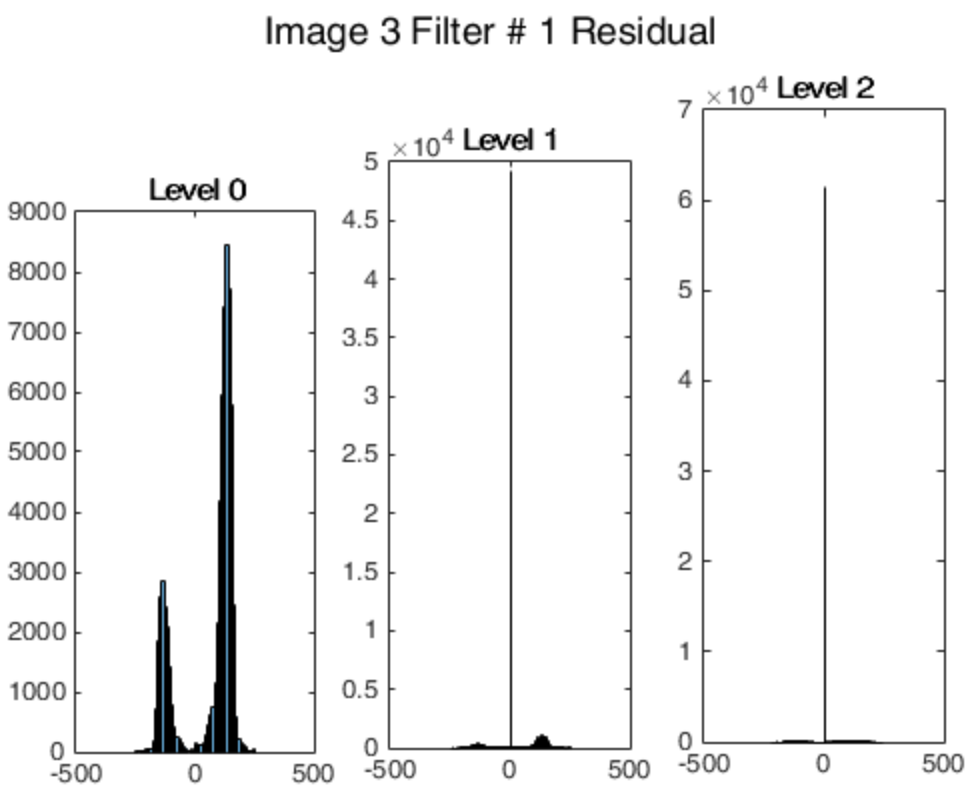


Image 1 Filter # 2 Residual

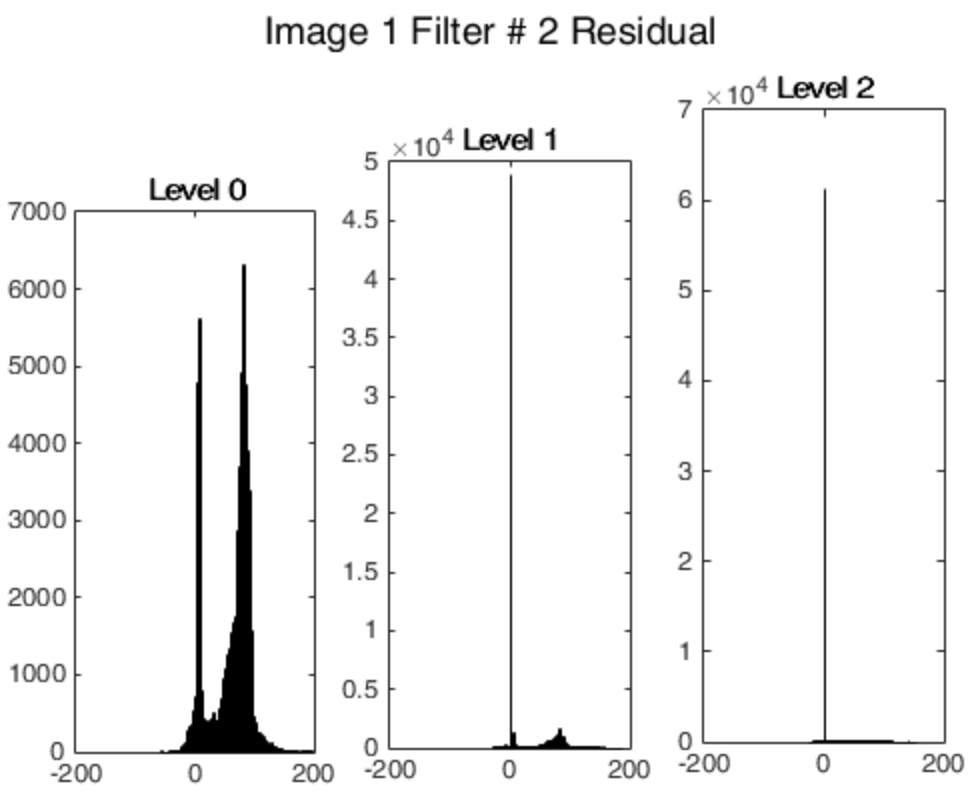


Image 1 Filter # 2 Residual
Level 0
×10^4 Level 1
×10^4 Level 2


Image 2 Filter # 2 Residual

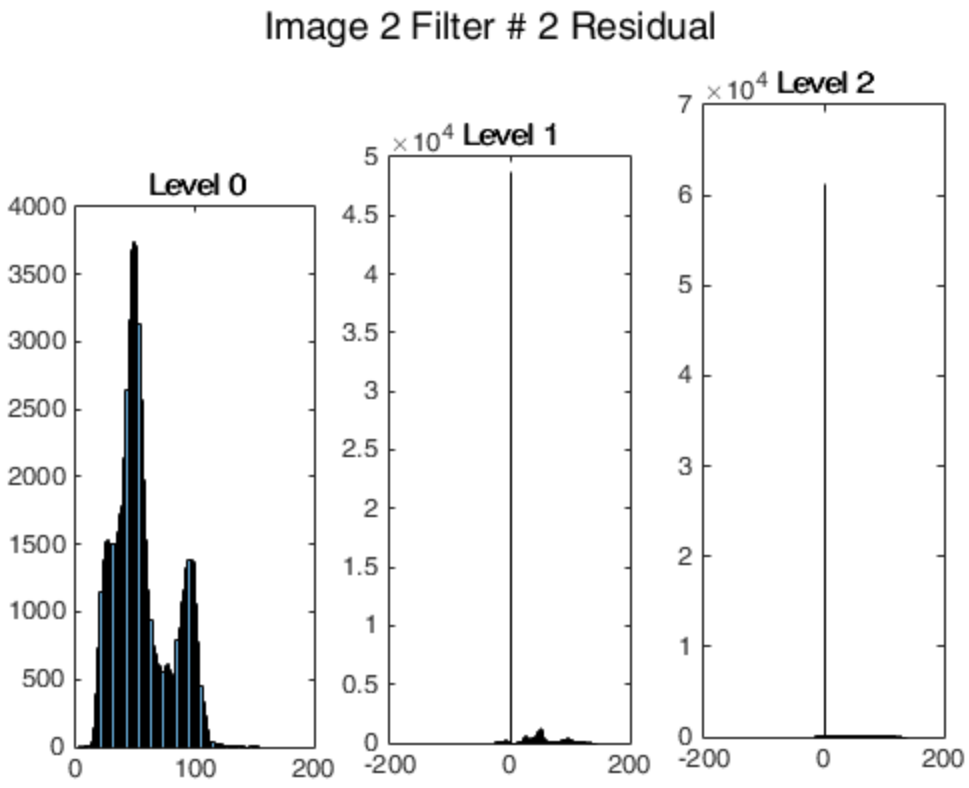


Image 2 Filter # 2 Residual
Level 0
Level 1
Level 2
×10^4
4000
3500
3000
2500
2000
1500
1000
500
0
100
200
-200
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
6
7

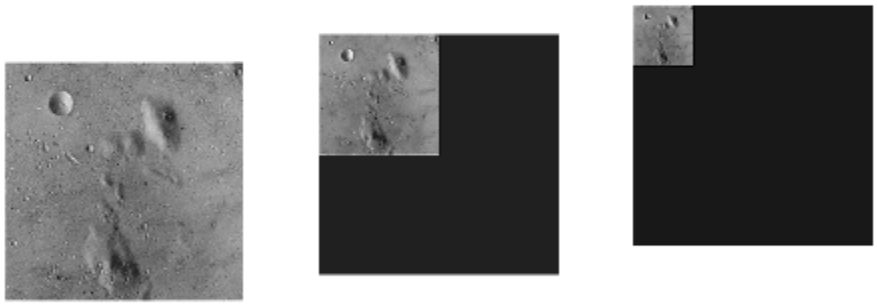


Image 3 Filter # 2 Residual

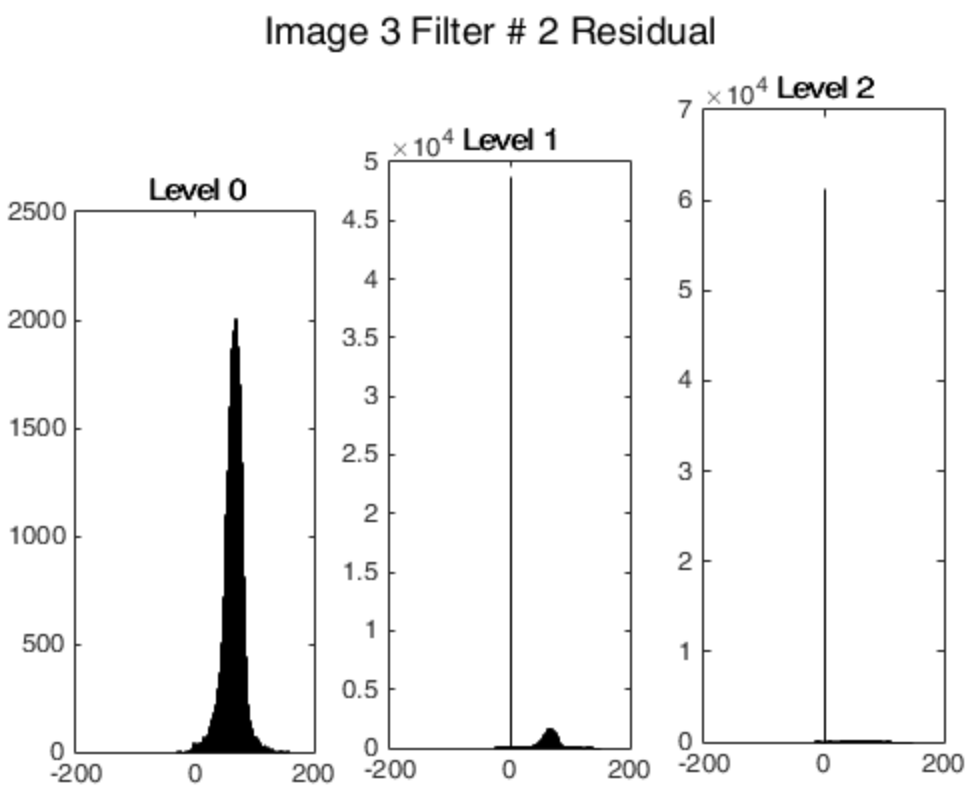


Image 3 Filter # 2 Residual
Level 0
Level 1
Level 2
×10^4
2500
2000
1500
1000
500
0
-200
0
200
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
7
6
5
4
3
2
1

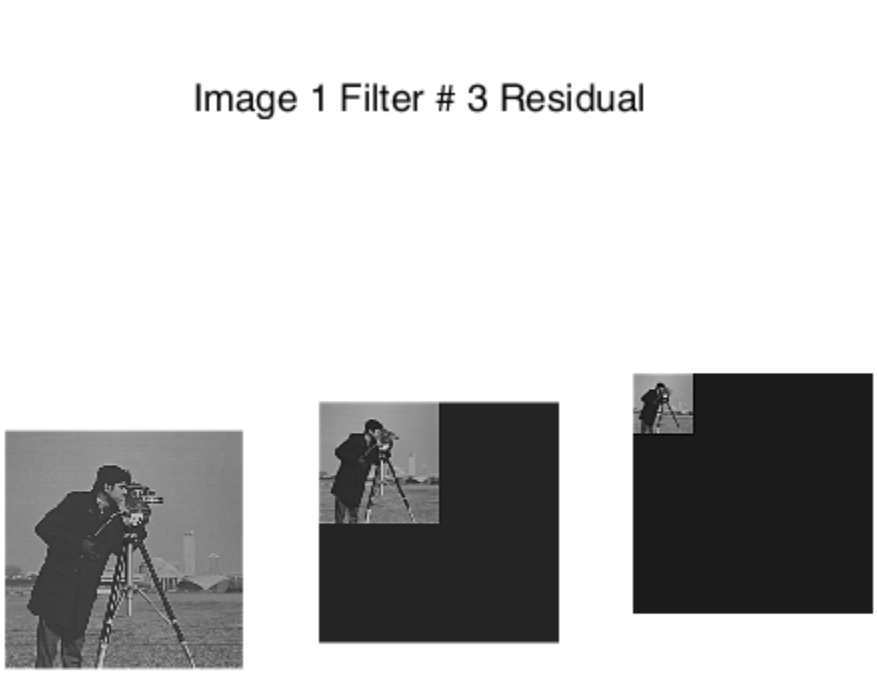


Image 1 Filter # 3 Residual

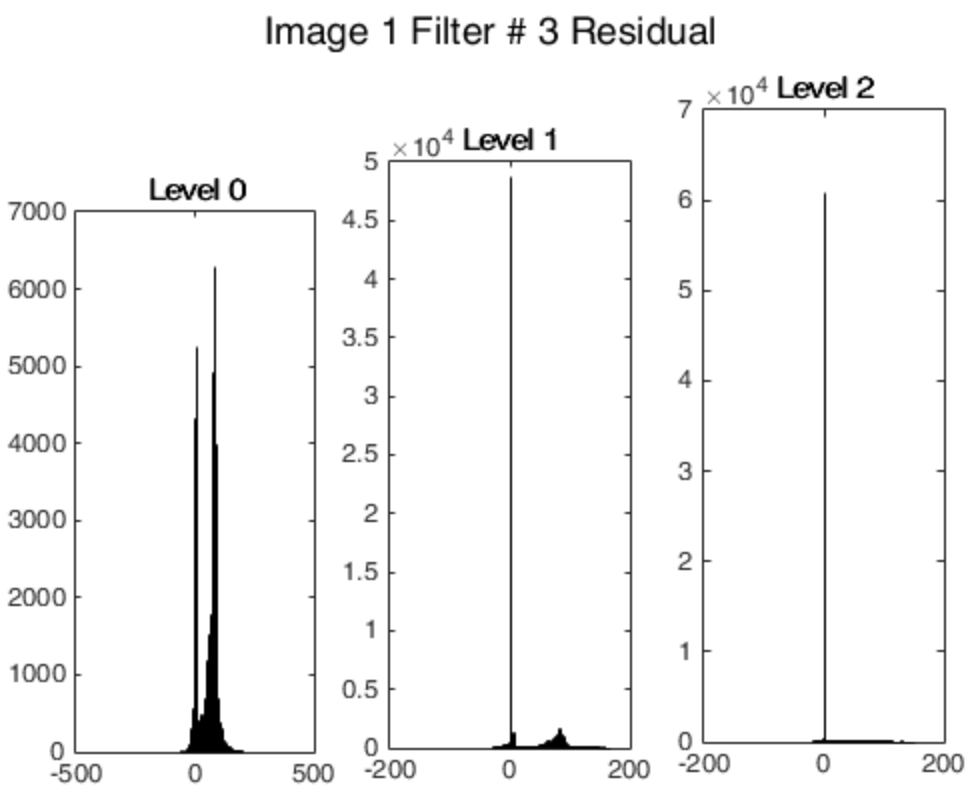


Image 2 Filter # 3 Residual

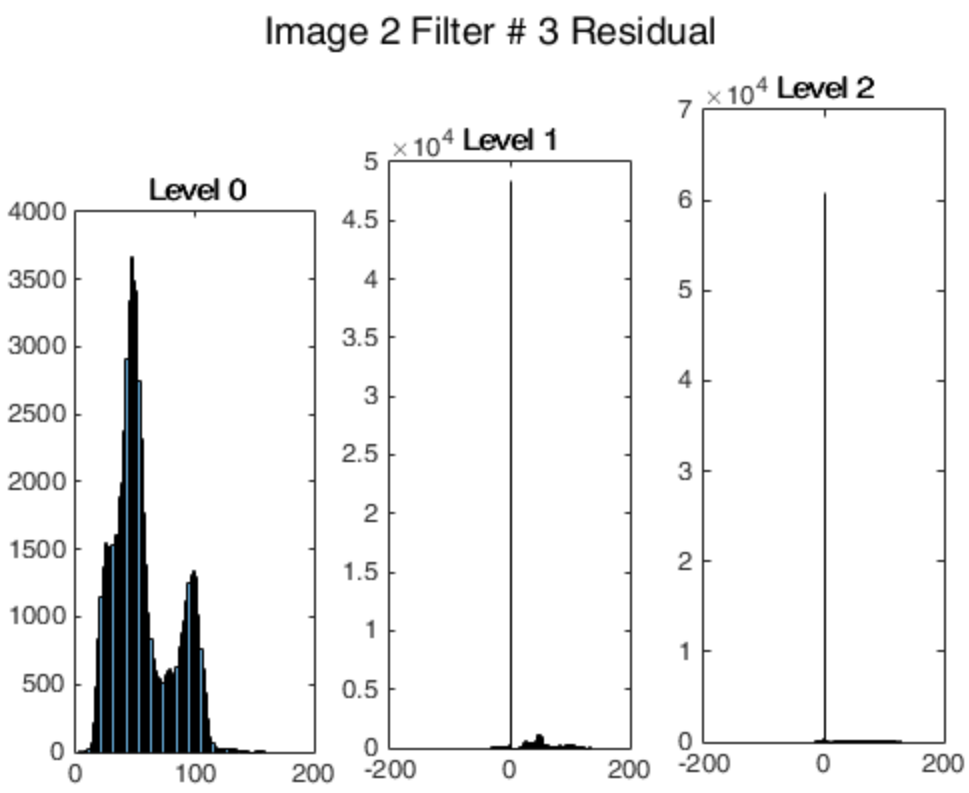


Image 2 Filter # 3 Residual
Level 0
Level 1
Level 2
×10^4
4000
3500
3000
2500
2000
1500
1000
500
0
100
200
-200
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
6
7

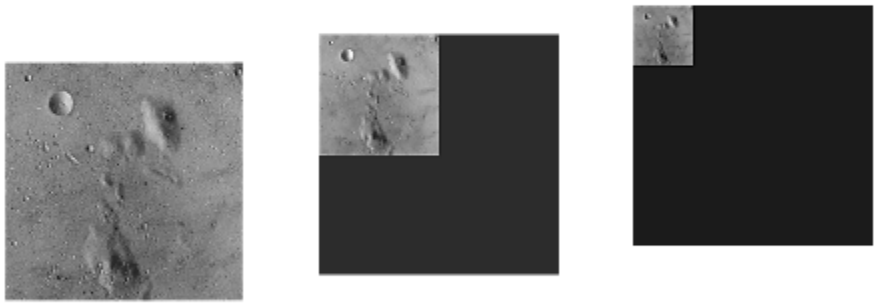


Image 3 Filter # 3 Residual

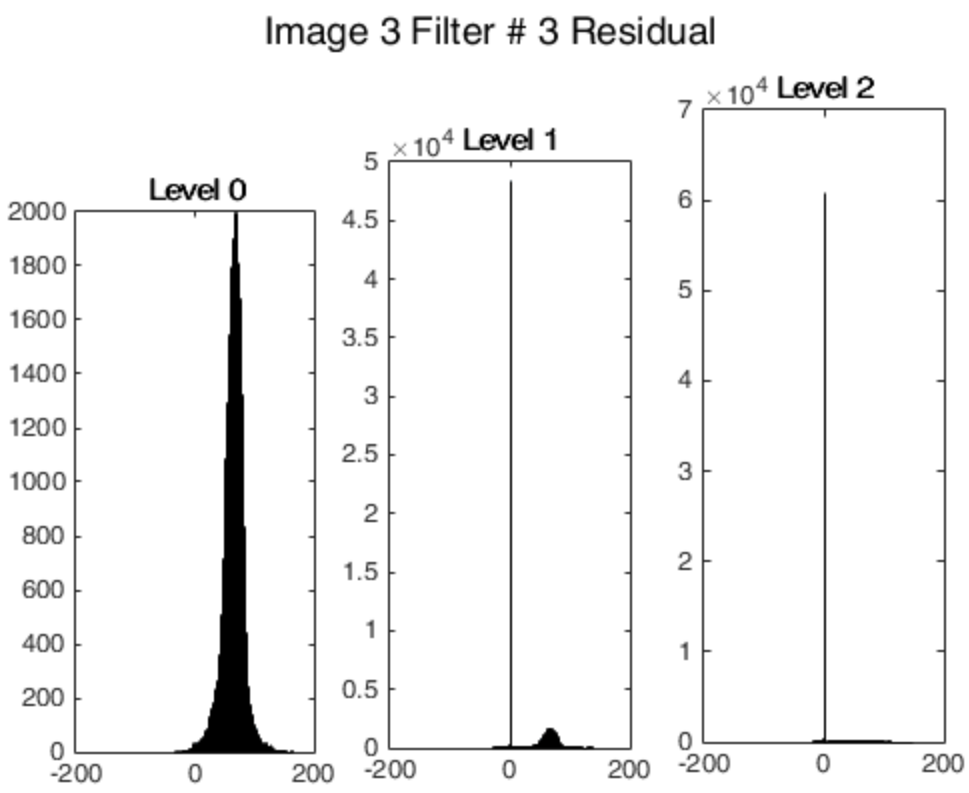


Image 1 Filter # 4 Residual

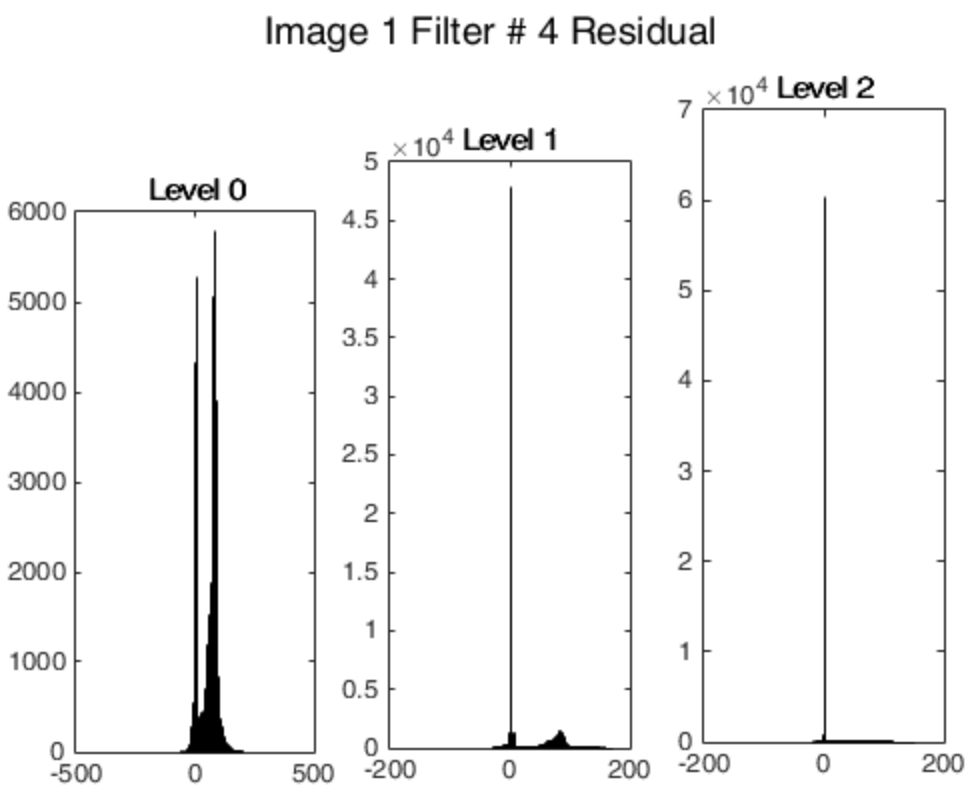


Image 2 Filter # 4 Residual

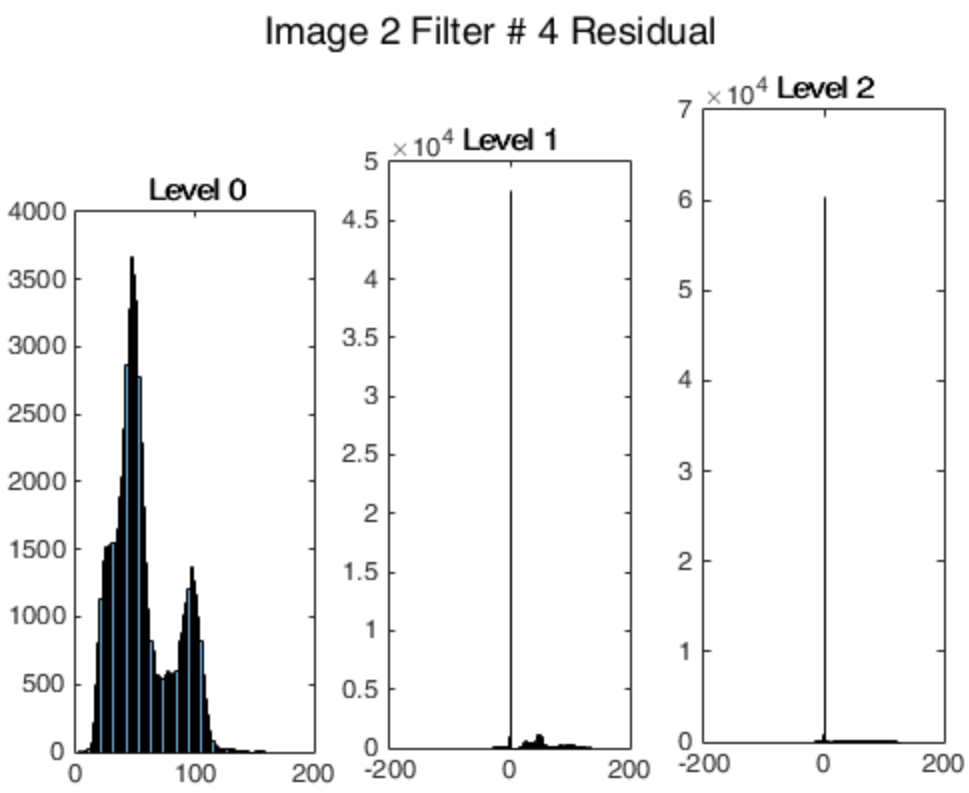


Image 2 Filter # 4 Residual
Level 0
Level 1
Level 2
×10^4
4000
3500
3000
2500
2000
1500
1000
500
0
100
200
-200
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
6
7

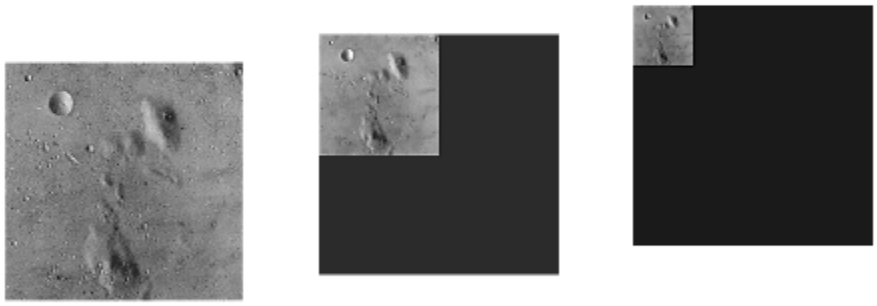


Image 3 Filter # 4 Residual

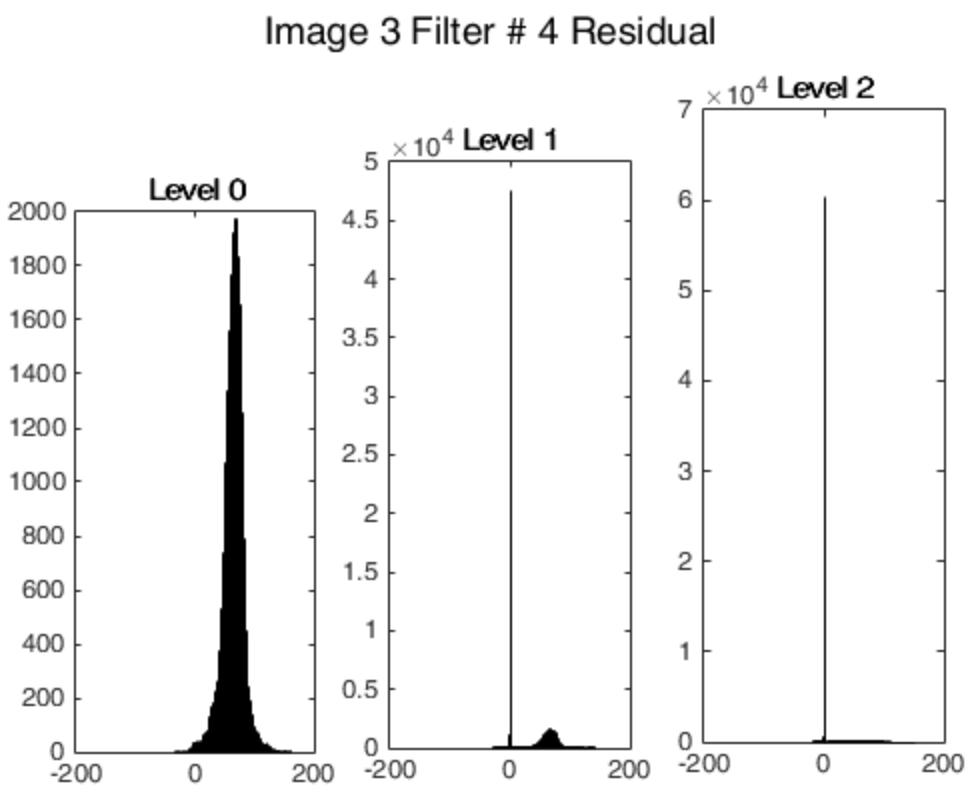


Image 1 Filter # 5 Residual

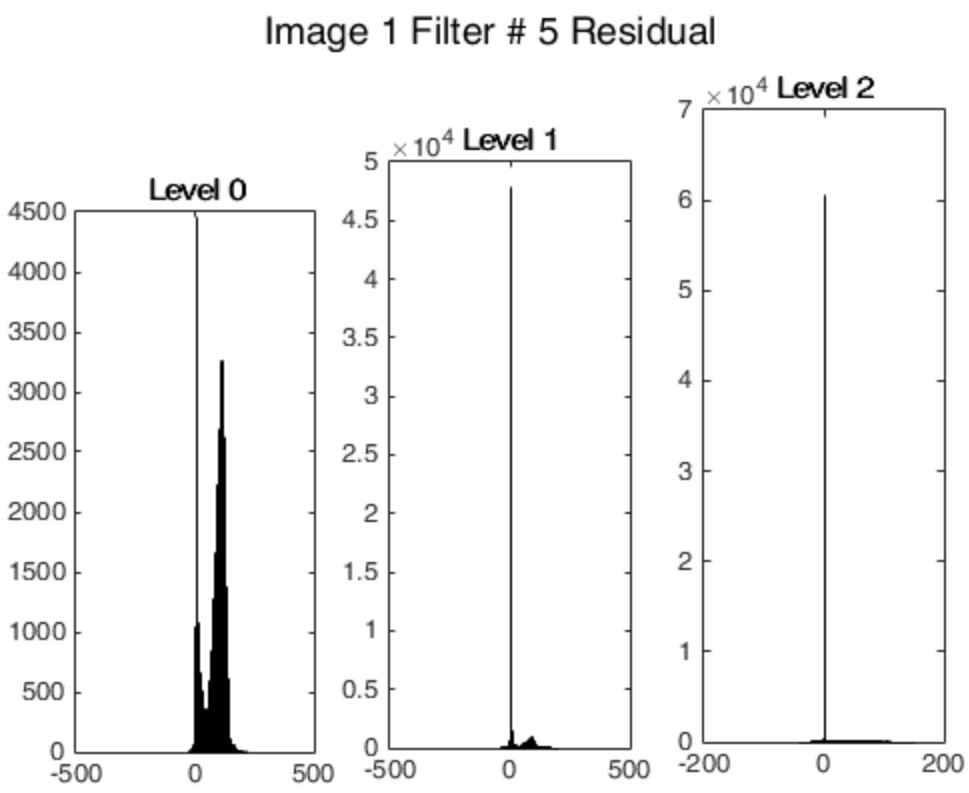


Image 1 Filter # 5 Residual
Level 0
Level 1
Level 2
×10^4
4500
4000
3500
3000
2500
2000
1500
1000
500
0
-500
0
500
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
7
6
5
4
3
2
1
-200
200


Image 2 Filter # 5 Residual

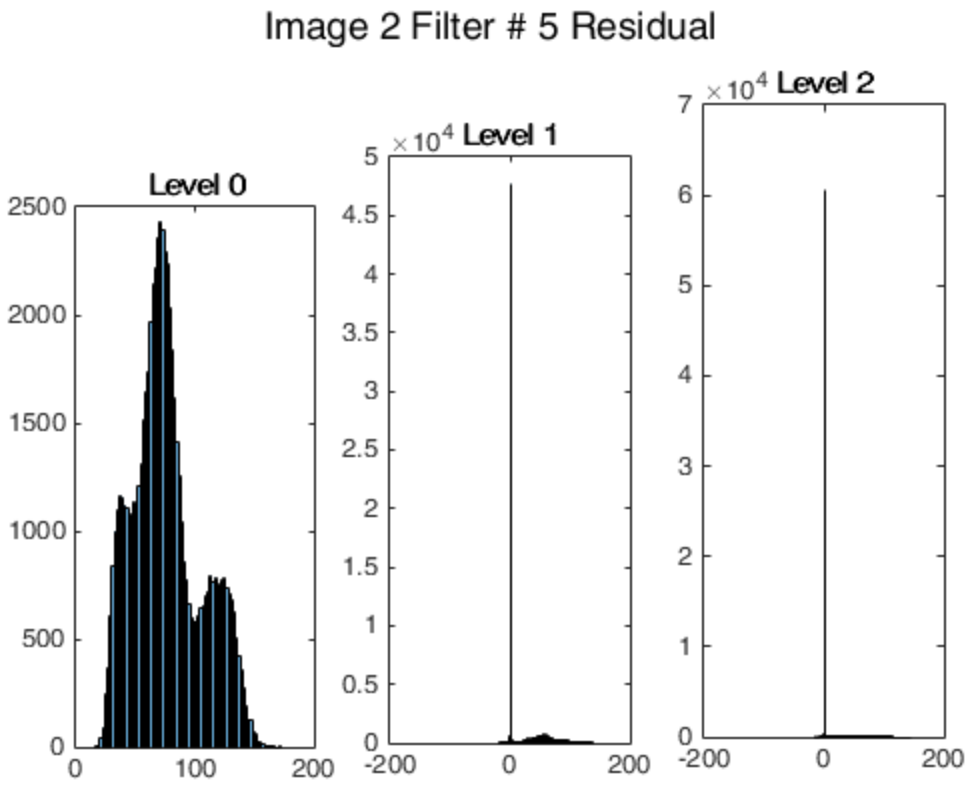


Image 2 Filter # 5 Residual
Level 0
Level 1
Level 2
×10^4
2500
2000
1500
1000
500
0
100
200
-200
4.5
3.5
2.5
1.5
0.5
6

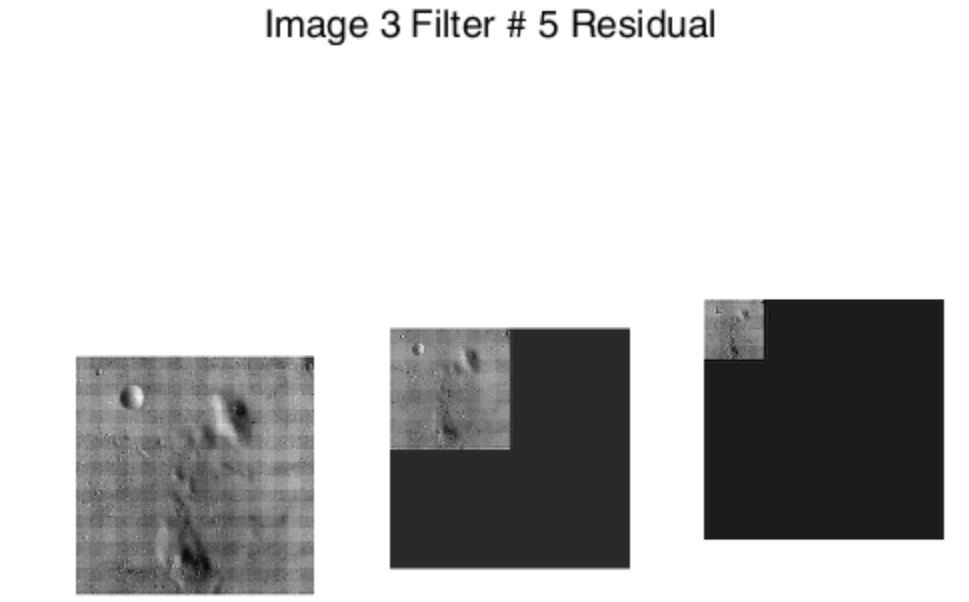
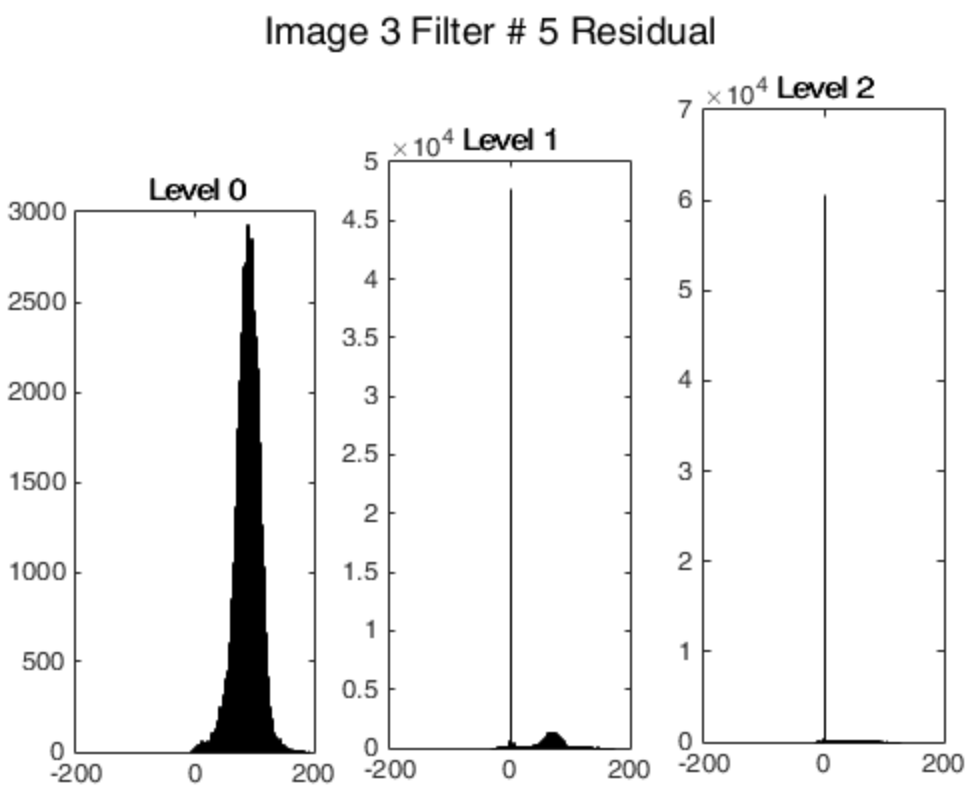


Image 3 Filter # 5 Residual



Problem 3

```
[edge1(:,:,1),thresh1] = edge(im(:,:,1),'Sobel');
[edge1(:,:,2),thresh2] = edge(im(:,:,1),'LoG');
[edge1(:,:,3),thresh3] = edge(im(:,:,1),'Canny');
[edge2(:,:,1),thresh4] = edge(im(:,:,2),'Sobel');
[edge2(:,:,2),thresh5] = edge(im(:,:,2),'LoG');
[edge2(:,:,3),thresh6] = edge(im(:,:,2),'Canny');
[edge3(:,:,1),thresh7] = edge(im(:,:,3),'Sobel');
[edge3(:,:,2),thresh8] = edge(im(:,:,3),'LoG');
[edge3(:,:,3),thresh9] = edge(im(:,:,3),'Canny');

fprintf('Image 1 Sobel Thresh: %d\n',thresh1);
fprintf('Image 1 LoG Thresh: %d\n',thresh2);
fprintf('Image 1 Canny Thresh: %d\n',thresh3);
fprintf('Image 2 Sobel Thresh: %d\n',thresh4);
fprintf('Image 2 LoG Thresh: %d\n',thresh5);
fprintf('Image 2 Canny Thresh: %d\n',thresh6);
fprintf('Image 3 Sobel Thresh: %d\n',thresh7);
fprintf('Image 3 LoG Thresh: %d\n',thresh8);
fprintf('Image 3 Canny Thresh: %d\n',thresh9);


edge4(:,:,1) = edge(im(:,:,1),'Sobel',2*thresh1);
edge4(:,:,2) = edge(im(:,:,1),'LoG',2*thresh2);
```

```
edge4(:,:,3) = edge(im(:,:,1),'Canny',2*thresh3);
edge5(:,:,1) = edge(im(:,:,2),'Sobel',2*thresh4);
edge5(:,:,2) = edge(im(:,:,2),'LoG',2*thresh5);
edge5(:,:,3) = edge(im(:,:,2),'Canny',2*thresh6);
edge6(:,:,1) = edge(im(:,:,3),'Sobel',2*thresh7);
edge6(:,:,2) = edge(im(:,:,3),'LoG',2*thresh8);
edge6(:,:,3) = edge(im(:,:,3),'Canny',2*thresh9);

edge7(:,:,1) = edge(im(:,:,1),'Sobel',thresh1/2);
edge7(:,:,2) = edge(im(:,:,1),'LoG',thresh2/2);
edge7(:,:,3) = edge(im(:,:,1),'Canny',thresh3/2);
edge8(:,:,1) = edge(im(:,:,2),'Sobel',thresh4/2);
edge8(:,:,2) = edge(im(:,:,2),'LoG',thresh5/2);
edge8(:,:,3) = edge(im(:,:,2),'Canny',thresh6/2);
edge9(:,:,1) = edge(im(:,:,3),'Sobel',thresh7/2);
edge9(:,:,2) = edge(im(:,:,3),'LoG',thresh8/2);
edge9(:,:,3) = edge(im(:,:,3),'Canny',thresh9/2);

figure;
subplot(1,3,1), imshow(edge1(:,:,1),[]);
title('Sobel');
subplot(1,3,2), imshow(edge1(:,:,2),[]);
title('LoG');
subplot(1,3,3), imshow(edge1(:,:,3),[]);
title('Canny');
suptitle('Image 1');

figure;
subplot(1,3,1), imshow(edge4(:,:,1),[]);
title('Sobel');
subplot(1,3,2), imshow(edge4(:,:,2),[]);
title('LoG');
subplot(1,3,3), imshow(edge4(:,:,3),[]);
title('Canny');
suptitle('Image 1, 2*thresh');

figure;
subplot(1,3,1), imshow(edge7(:,:,1),[]);
title('Sobel');
subplot(1,3,2), imshow(edge7(:,:,2),[]);
title('LoG');
subplot(1,3,3), imshow(edge7(:,:,3),[]);
title('Canny');
suptitle('Image 1, thresh/2');

figure;
subplot(1,3,1), imshow(edge2(:,:,1),[]);
title('Sobel');
subplot(1,3,2), imshow(edge2(:,:,2),[]);
title('LoG');
subplot(1,3,3), imshow(edge2(:,:,3),[]);
title('Canny');
suptitle('Image 2');
```

```
figure;
subplot(1,3,1), imshow(edge5(:,:,1),[]);
title('Sobel');
subplot(1,3,2), imshow(edge5(:,:,2),[]);
title('LoG');
subplot(1,3,3), imshow(edge5(:,:,3),[]);
title('Canny');
suptitle('Image 2, 2*thresh');

figure;
subplot(1,3,1), imshow(edge8(:,:,1),[]);
title('Sobel');
subplot(1,3,2), imshow(edge8(:,:,2),[]);
title('LoG');
subplot(1,3,3), imshow(edge8(:,:,3),[]);
title('Canny');
suptitle('Image 2, thresh/2');

figure;
subplot(1,3,1), imshow(edge3(:,:,1),[]);
title('Sobel');
subplot(1,3,2), imshow(edge3(:,:,2),[]);
title('LoG');
subplot(1,3,3), imshow(edge3(:,:,3),[]);
title('Canny');
suptitle('Image 3');

figure;
subplot(1,3,1), imshow(edge6(:,:,1),[]);
title('Sobel');
subplot(1,3,2), imshow(edge6(:,:,2),[]);
title('LoG');
subplot(1,3,3), imshow(edge6(:,:,3),[]);
title('Canny');
suptitle('Image 3, 2*thresh');

figure;
subplot(1,3,1), imshow(edge9(:,:,1),[]);
title('Sobel');
subplot(1,3,2), imshow(edge9(:,:,2),[]);
title('LoG');
subplot(1,3,3), imshow(edge9(:,:,3),[]);
title('Canny');
suptitle('Image 3, thresh/2');

disp('Increasing the threshold cuts out more edges, decreasing the
 threshold increases the number of edges allowed through. In general
 performance is the same for each filter type across thresholds.');
```

```
Image 1 Sobel Thresh: 1.433227e-01
Image 1 LoG Thresh: 5.093515e-03
Image 1 Canny Thresh: 3.125000e-02
Image 1 Canny Thresh: 7.812500e-02
Image 2 Sobel Thresh: 1.161891e-01
```

```
Image 2 LoG Thresh: 7.456524e-03
Image 2 Canny Thresh: 1.750000e-01
Image 2 Canny Thresh: 4.375000e-01
Image 3 Sobel Thresh: 6.744113e-02
Image 3 LoG Thresh: 2.594287e-03
Image 3 Canny Thresh: 3.750000e-02
Image 3 Canny Thresh: 9.375000e-02
Increasing the threshold cuts out more edges, decreasing the threshold
 increases the number of edges allowed through. In general performance
 is the same for each filter type across thresholds.
```

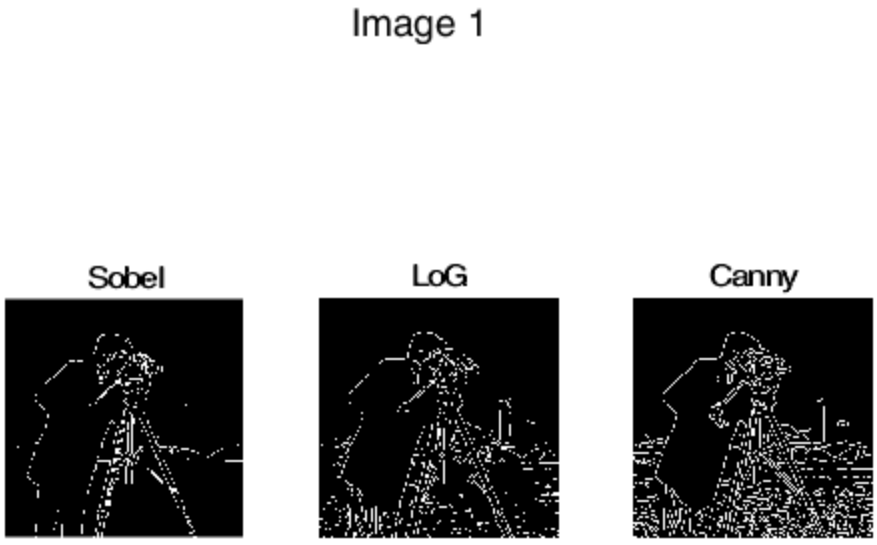


Image 1, 2*thresh

Sobel

LoG

Canny

Image 1, thresh/2

Sobel

LoG

Canny

Image 2

Image 2, 2*thresh

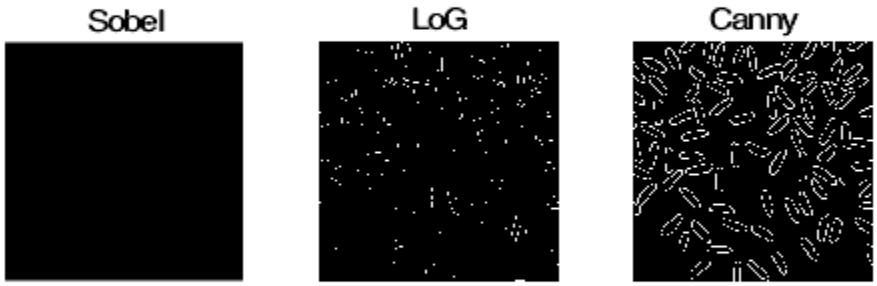


Image 2, thresh/2

Image 3

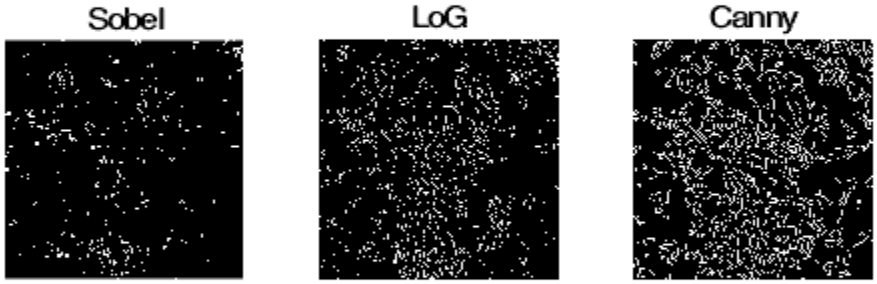


Image 3, 2*thresh

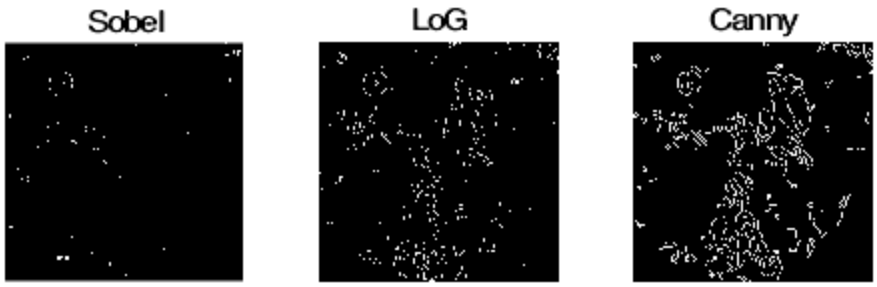
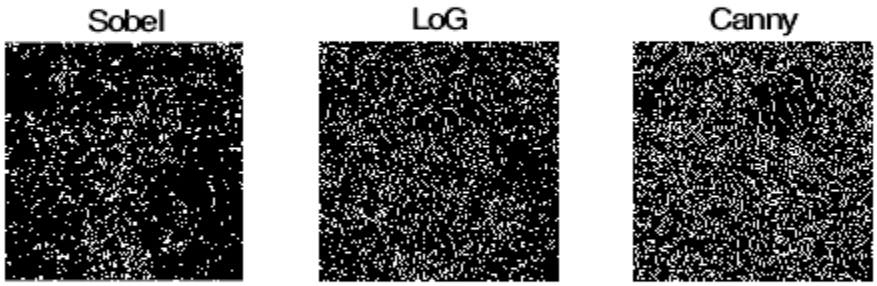


Image 3, thresh/2



Published with MATLAB® R2015a