Particle Image Velocity

Table of Contents

```
clc
clear
close all
```

Import image data

```
I1=imread('00020359.bmp');
I2=imread('00020360.bmp');
I3=imread('00020361.bmp');
I4=imread('00020362.bmp');
```

Set image processing values

```
thresholdRatio=0.5; % Particles above this ratio*maximum intensity
 will remain
r1 = 1; % Circle recognition radii
r2 = 3;
```
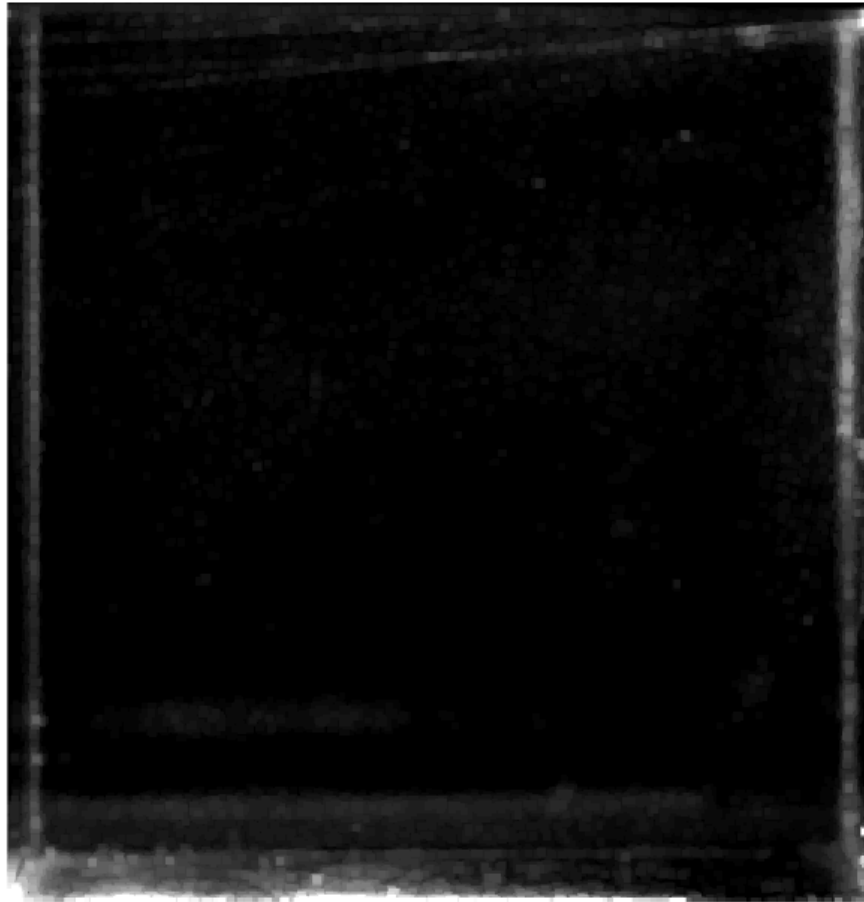
Filtering for I1

```
imshow(I1)
title('Original I1')
foreground1 = backgroundFilter(I1,'I1');
maximumIntensity1 = max(max(foreground1));
threshold1 = maximumIntensity1*thresholdRatio;
filtered1 = thresholdFilter(foreground1, threshold1,'I1');
I1f = filtered1;
```
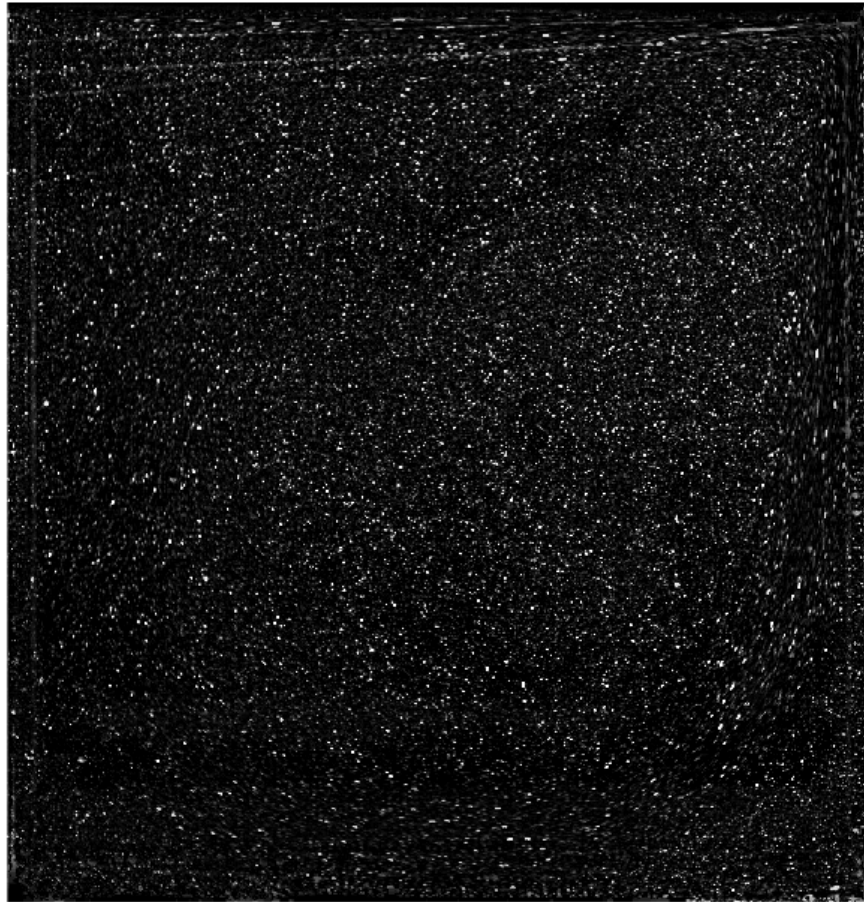
Original I1
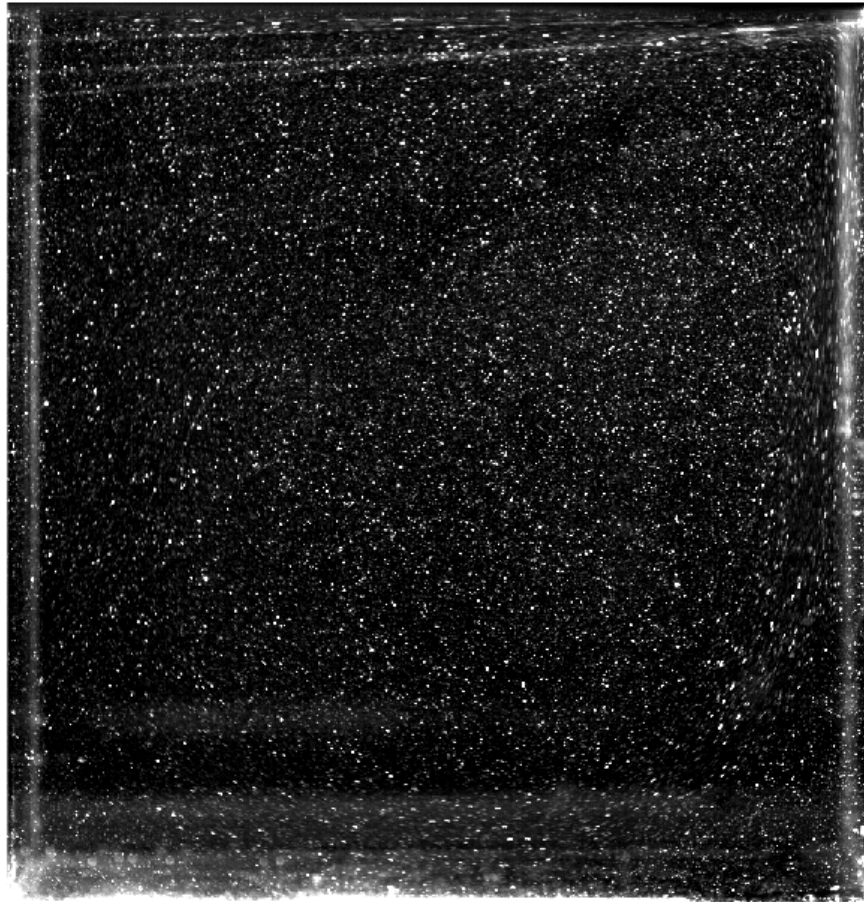
Foreground I1

Background I1

Filtered I1

Filterring for I2

```
figure
imshow(I2)
title('Original I2')
foreground2 = backgroundFilter(I2,'I2');
maximumIntensity2 = max(max(foreground2));
threshold2 = maximumIntensity2*thresholdRatio;
filtered2 = thresholdFilter(foreground2, threshold2,'I2');
I2f = filtered2;
```
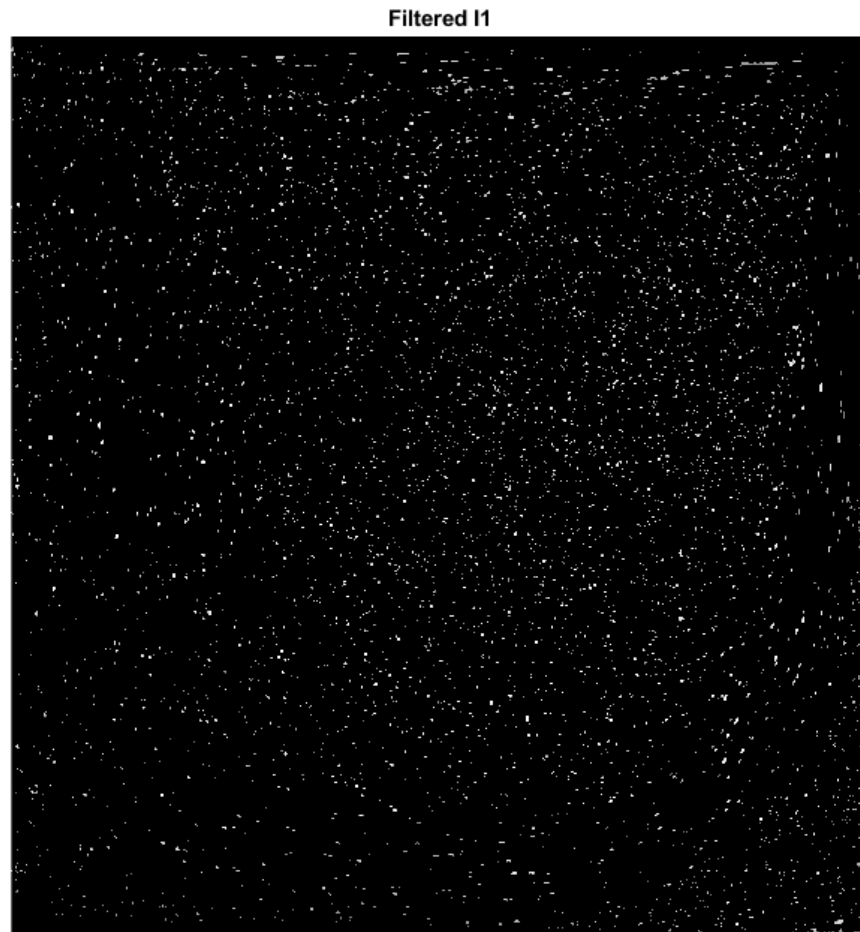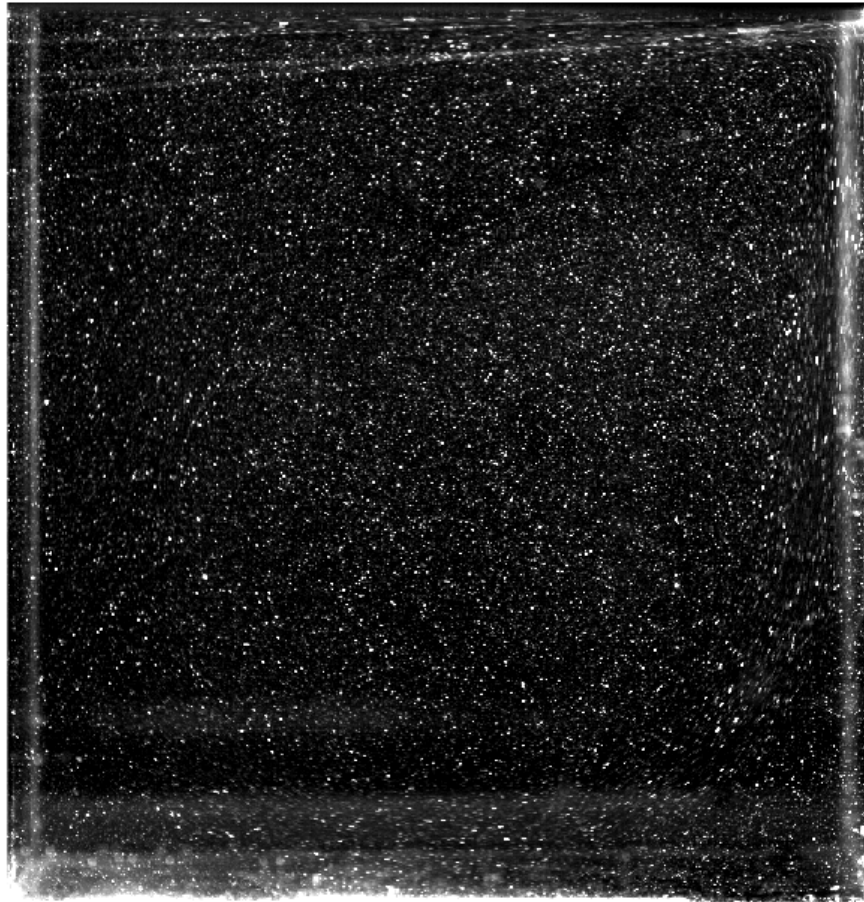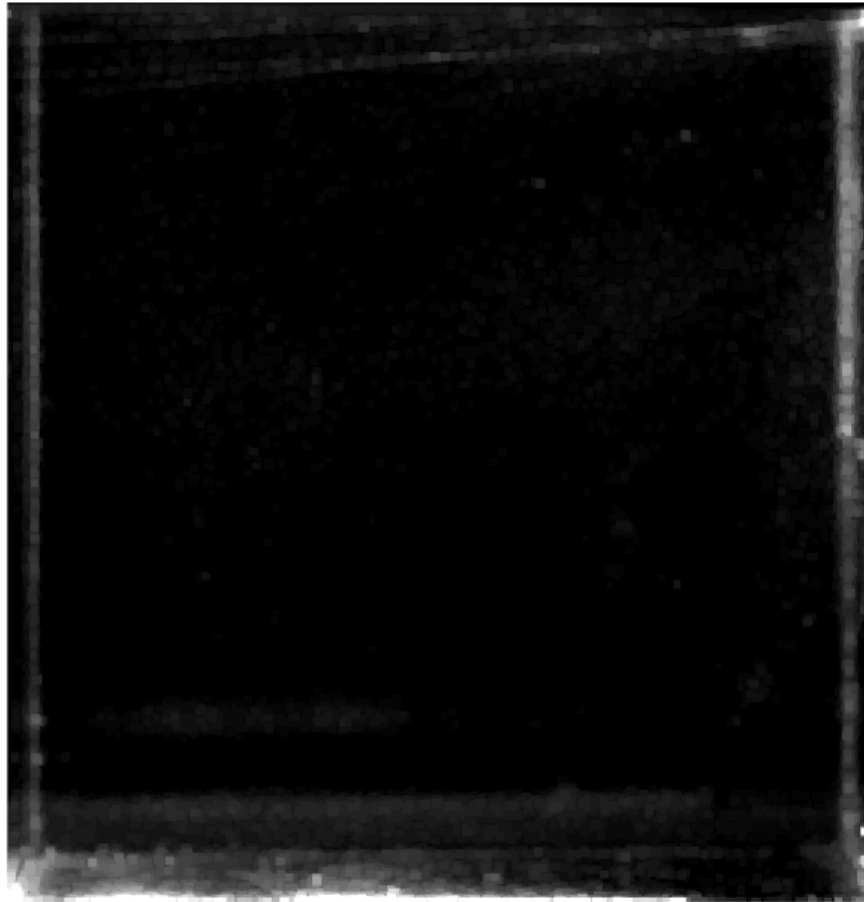
Original I2

Foreground I2

Background I2

Filtered I2
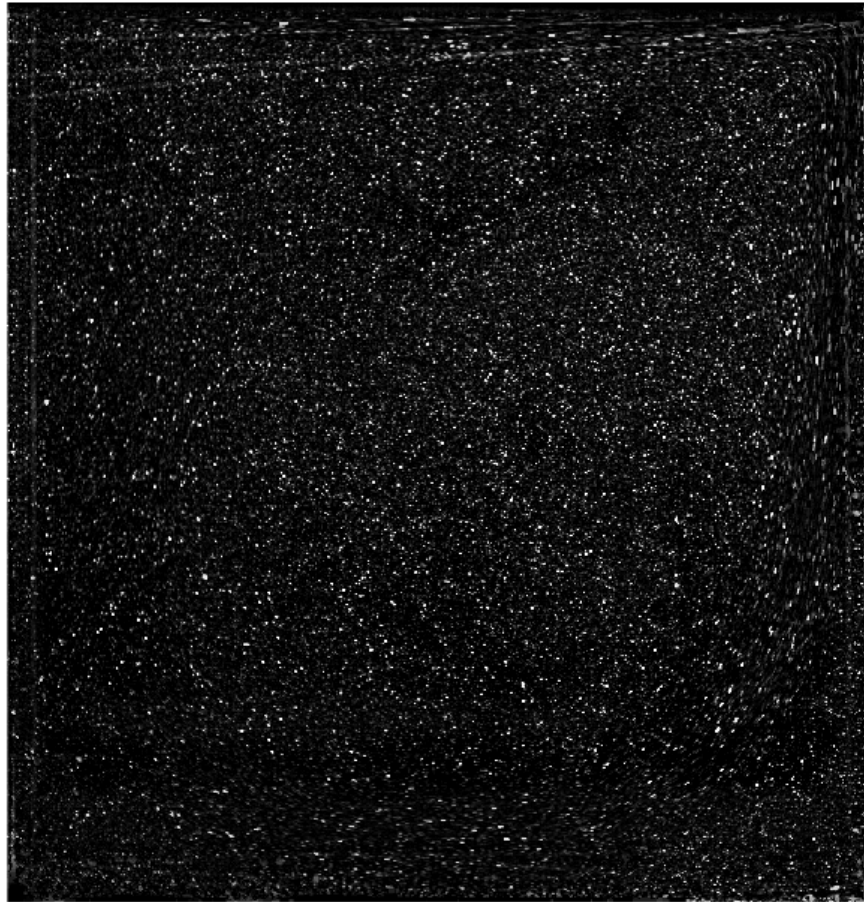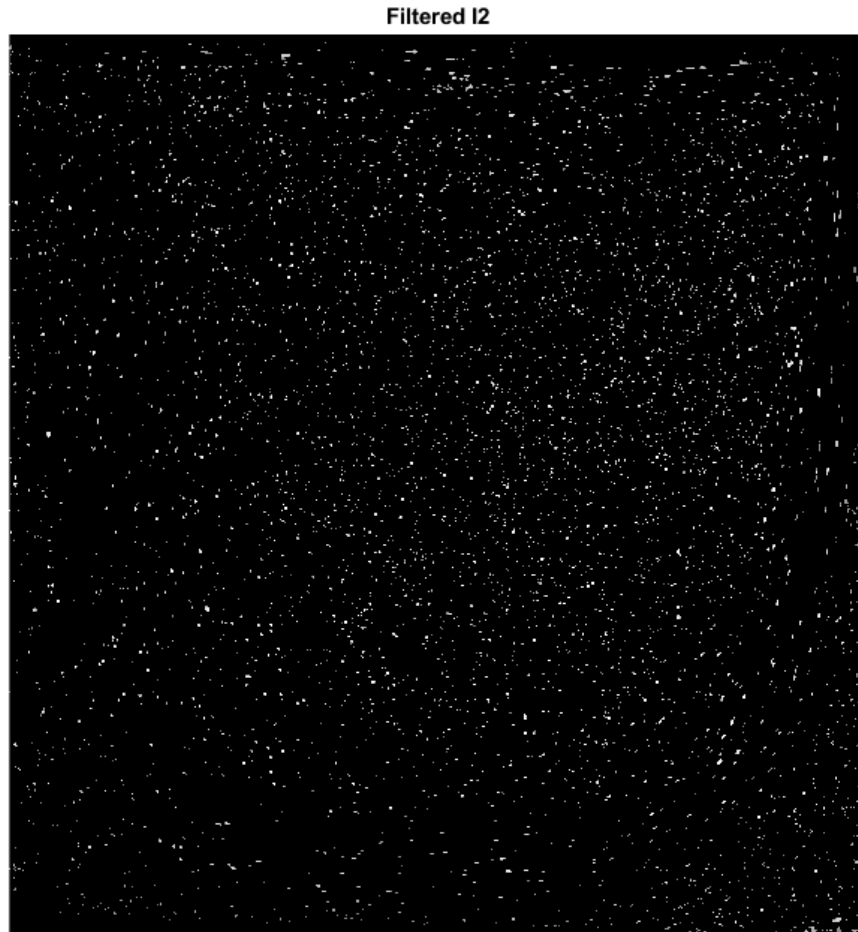
Interrogation window calculation

```
[iwLength1,meanParticleSize1,numParticles1] =
 windowCalcCircle(I1f,r1,r2,1);
```

Warning: You just called IMFINDCIRCLES with very small radius value(s).
Algorithm accuracy is limited for radius values less than or equal to 5.

Filtered I2

Identified circles shown in red circles
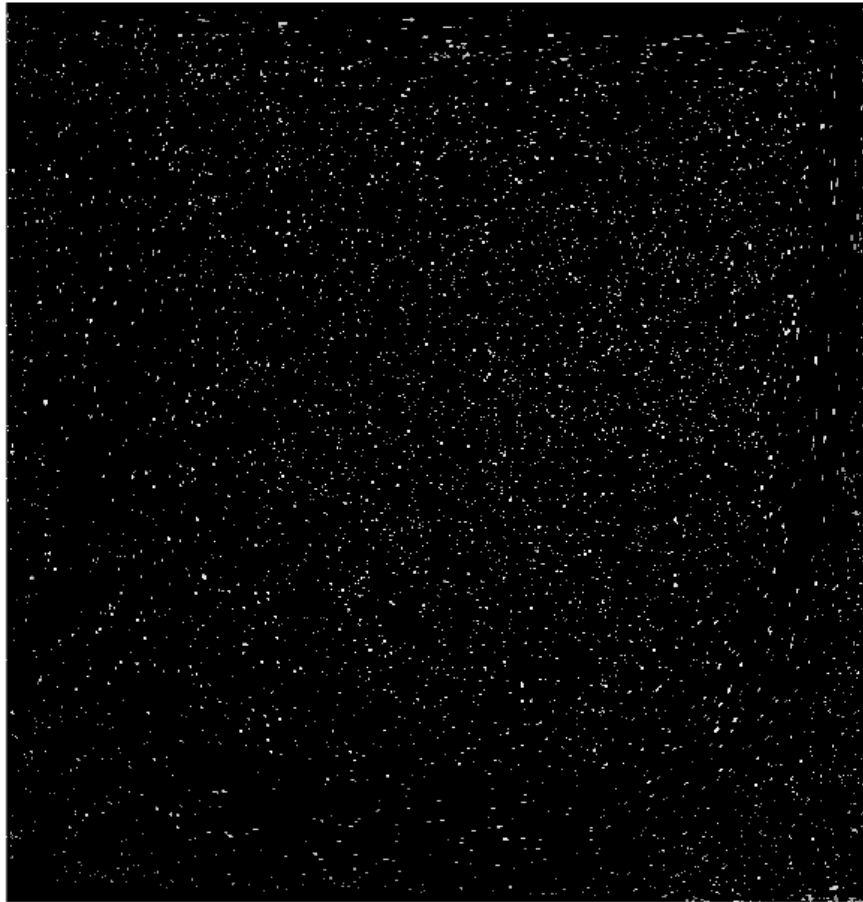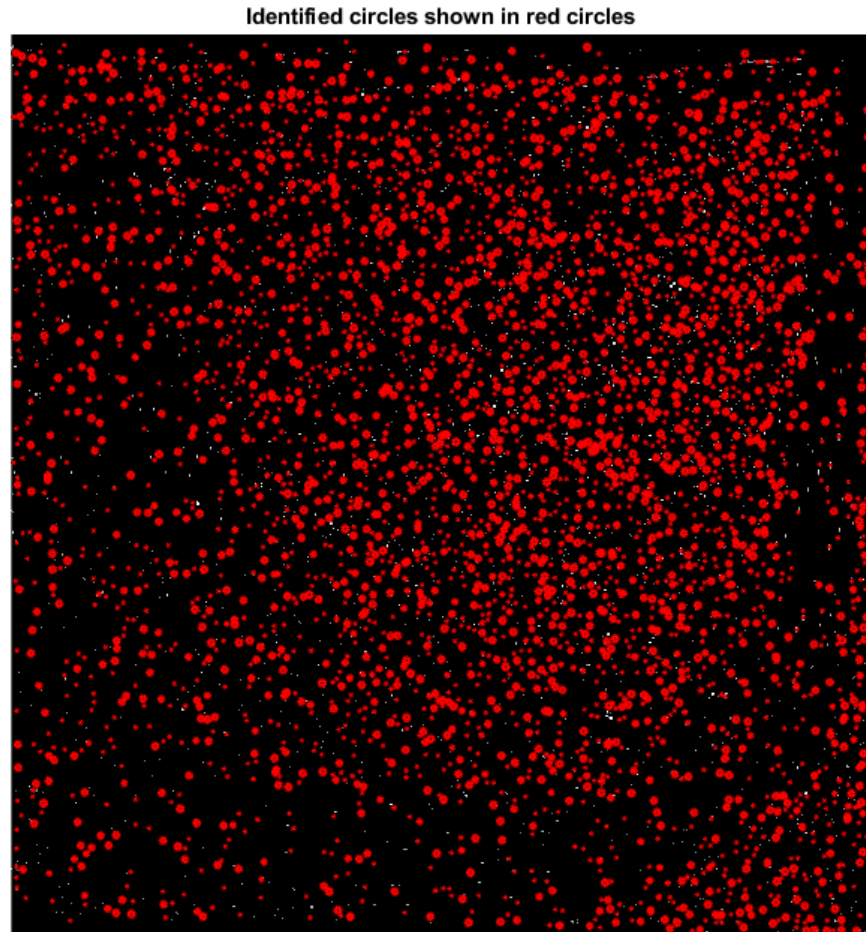
Alternate interrogation window calculation

```
[iwLength,meanParticleSize,numParticles] = windowCalcObject(I1f,1);
```

Particles shown in multiple colors.

Print values

```
maximumIntensity1
meanParticleSize
iwLength
```

maximumIntensity1 =

   uint8

    255

meanParticleSize =

     2.4948

iwLength =

32

Particle number calculation

```
ii=1;
jj=1;
[sx,sy] = size(I1f);
for i=0:iwLength:sx-iwLength
    for j=0:iwLength:sy-iwLength
        crop1=imcrop(I1f,[i,j,iwLength,iwLength]);
        %[empty,empty,numParticlesMatrix1(ii,jj)] =
 windowCalcCircle(crop1,r1,r2,0);
        [empty,empty,numParticlesMatrix1(ii,jj)] =
 windowCalcObject(crop1,0);
        jj = jj+1;
    end
    jj=1;
    ii = ii+1;
end
densityMesh(numParticlesMatrix1)
```

Particles shown in multiple colors.

Number of particles per interrogation window
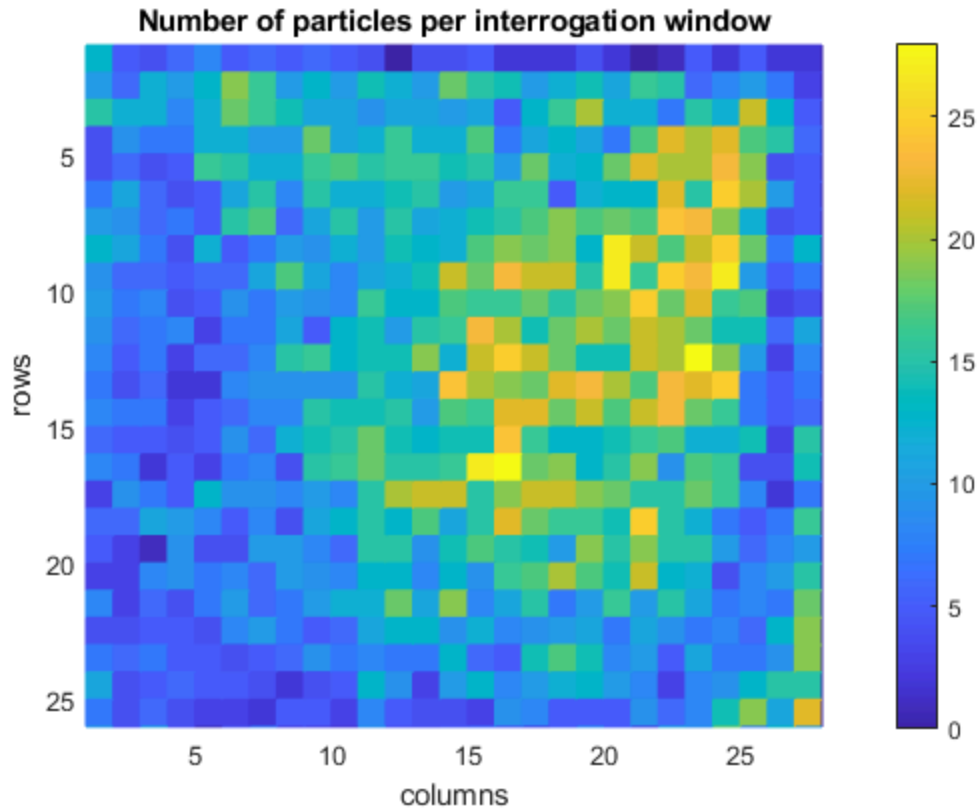
Velocity calculation

```
ii=1;
jj=1;
for i=0:iwLength:sx-iwLength
    for j=0:iwLength:sy-iwLength
        y = j+1;
        Y = y+iwLength-1;
        x = i+1;
        X = x+iwLength-1;
        szy = y:Y;
        szx = x:X;

        nimg1 = I1-mean(mean(I1));
        nSec1 = nimg1(szx,szy);

        nimg2 = I2-mean(mean(I2));
        szx2 = x-iwLength*2:x+5*iwLength;
        szy2 = y-iwLength*2:y+5*iwLength;
        szx2 = szx2(szx2>0 & szx2<=size(I1,1));
        szy2 = szy2(szy2>0 & szy2<=size(I1,2));
        nSec2 = nimg2(szx2,szy2);

        if isequal(nSec1,zeros(size(nSec1,1),size(nSec1,2)))...
                || isequal(nSec2,zeros(size(nSec2,1),size(nSec2,2)))
```

```
            shifty(ii,jj)=0;
            shiftx(ii,jj)=0;
        else
            crr = normxcorr2(nSec1,nSec2);
            [ssr,snd] = max(crr(:));
            [ij,ji] = ind2sub(size(crr),snd);
            shifty(ii,jj)=ij-x-size(nSec1,1)+1+szx2(1)-1;
            shiftx(ii,jj)=ji-y-size(nSec1,2)+1+szy2(1)-1;
        end
        if ii==ceil((sx-iwLength)/iwLength)/2 && jj==ceil((sy-
iwLength)/iwLength)/2
            figure
            mesh(crr)
            title('Center interrogation window correlation plane')
        end

        jj = jj+1;
    end
    jj=1;
    ii = ii+1;
end
```


Number of particles per interrogation window

Center interrogation window correlation plane
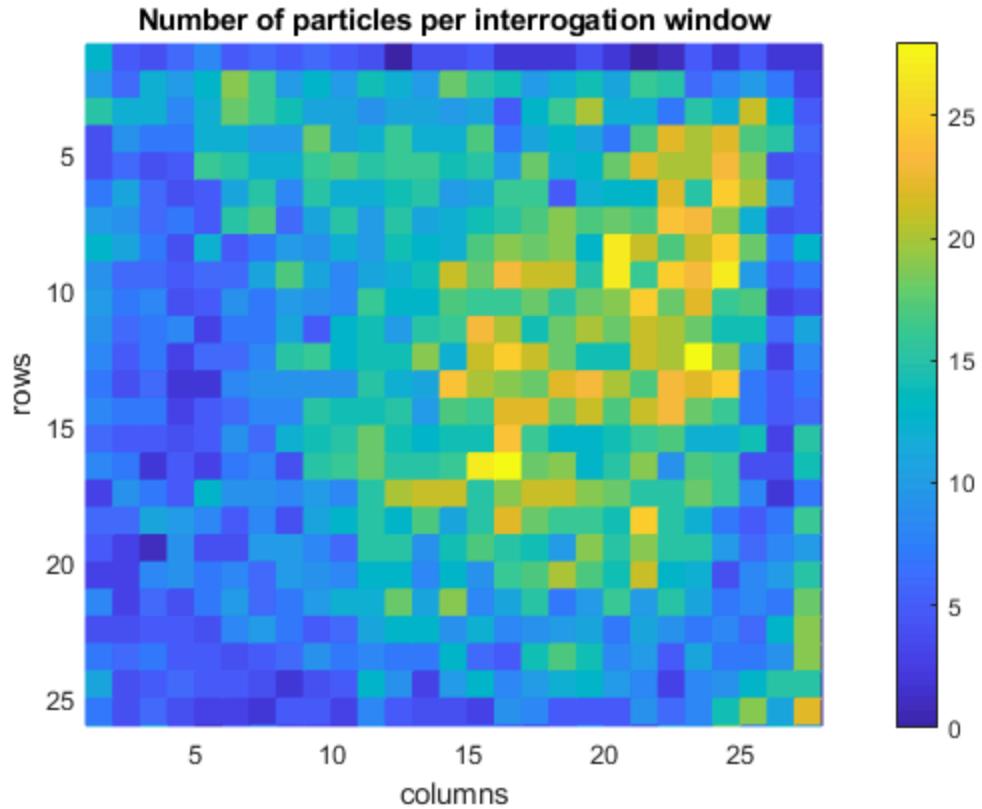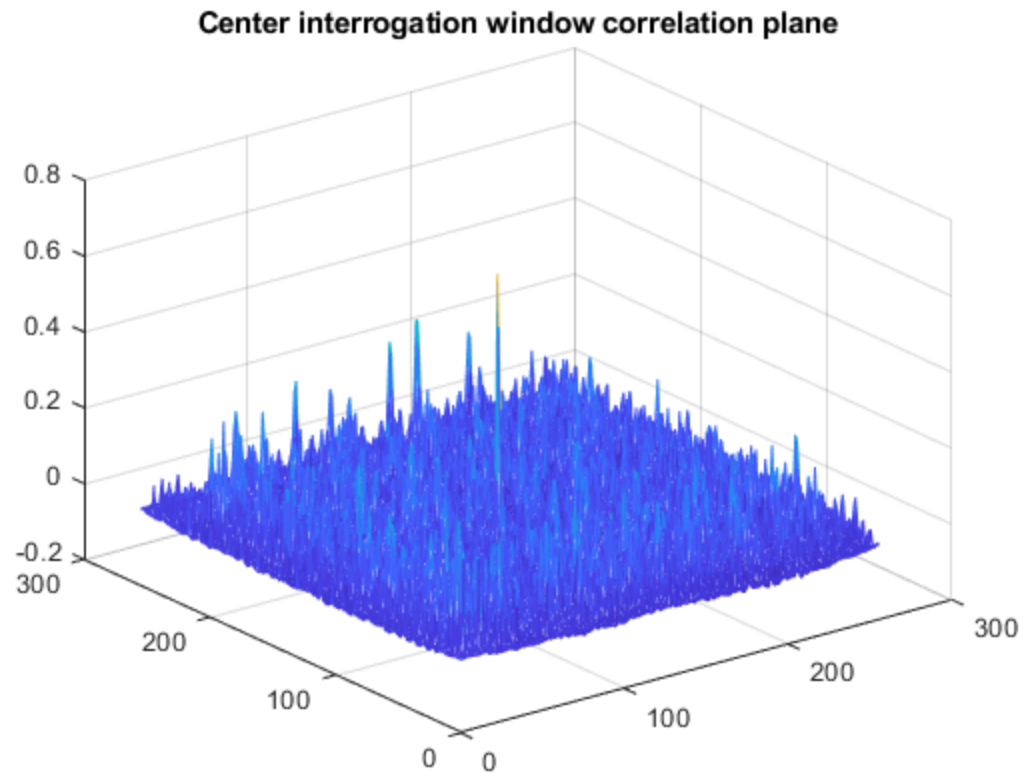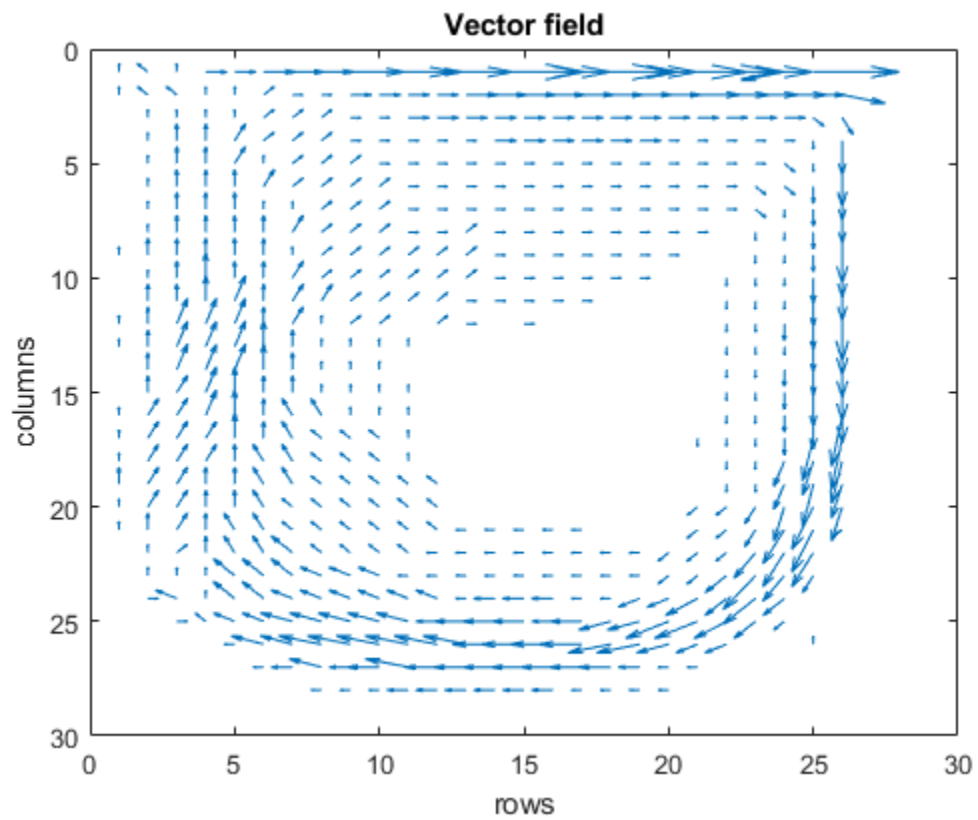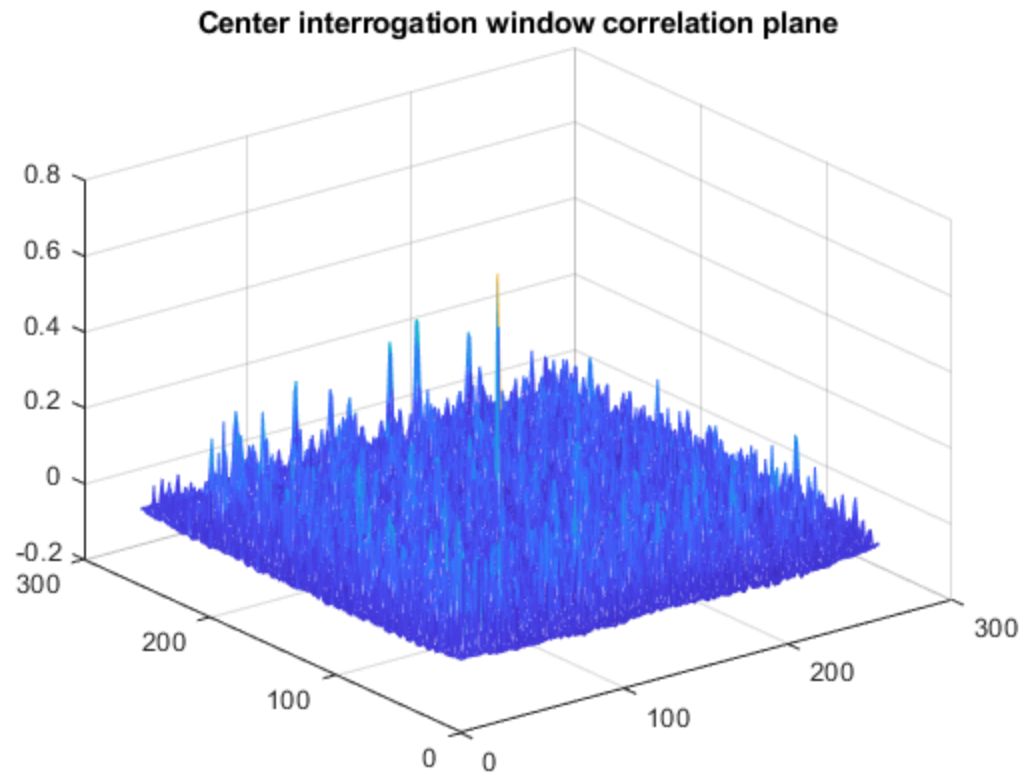

Vector field graphing

```
figure
quiver(shiftx,shifty,'AutoScaleFactor',3)
set(gca,'View',[0 270])
xlabel('rows')
ylabel('columns')
title('Vector field')
```

Center interrogation window correlation plane

Vector field

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```matlab
function [foreground] = backgroundFilter(I, name)

background = imopen(I,strel('square',7));
figure
imshow(background)
title(join(['Foreground ' name]))
foreground=I-background;
figure
imshow(foreground)
title(join(['Background ' name]))
```

Not enough input arguments.

Error in backgroundFilter (line 3)
background = imopen(I,strel('square',7));

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```matlab
function [filtered] = thresholdFilter(I, threshold, name)

Itemp=I>threshold;
filtered = uint8(int16(I).*int16(Itemp));
figure
imshow(filtered)

title(join(['Filtered ' name]))
```

Not enough input arguments.

Error in thresholdFilter (line 3)
Itemp=I>threshold;

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```matlab
function [iwLength,meanParticleSize,numParticles] =
 windowCalcCircle(I,r1,r2,print)


[centers,radii] = imfindcircles(I,
[r1,r2],'ObjectPolarity','bright','Sensitivity',1);
meanParticleSize = (pi*(mean(radii))^2);
[sx,sy] = size(I);
[np1,np2] = size(centers);
numParticles = np1*np2;
particleDensity = numParticles/(sx*sy);
iwArea = 10/particleDensity;
iwLength = round(sqrt(iwArea));
if print == 1
    figure
    imshow(I)
    viscircles(centers,radii);
    title('Identified circles shown in red circles')
end
```

Not enough input arguments.

Error in windowCalcCircle (line 4)
[centers,radii] = imfindcircles(I,
[r1,r2],'ObjectPolarity','bright','Sensitivity',1);

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```matlab
function [iwLength,meanParticleSize,numParticles] =
 windowCalcObject(I,print)

objects = bwconncomp(I,8);
labeled = labelmatrix(objects);
numParticles = objects.NumObjects;
meanParticleSize = nnz(labeled)/numParticles;
[sx,sy] = size(I);
particleDensity = numParticles/(sx*sy);
iwArea = 10/particleDensity;
iwLength = round(sqrt(iwArea));

if print == 1
    figure
    RGB = label2rgb(labeled,'spring','c','shuffle');
  %,'spring','c','shuffle'
    imshow(RGB)
    title('Particles shown in multiple colors.')
end
```

Not enough input arguments.

Error in windowCalcObject (line 3)
objects = bwconncomp(I,8);

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