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Description

```
%title: Hybrid Algorithm
%desc: an IFTA to determine phase distribution in CGH for beam shaping
%using amplitude freedom in certain region
%author: Muhammad Syahman Samhan
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%last update: November 21, 2019
%adapted from Gerchberg and Saxton (1971), Pasienski & DeMarco (2008),
%Gaunt A. L. & Hadzibabic Z. (2012), and Zhou W. (2018).
%inspired from
    %1. Musa Aydin (Sultan Mehmet Vakif University)
    %2. Dae Gwang Choi (KAIST, 2019)
    %3. Pasienski & DeMarco (2008)
```

General Variables

```
clc
clear all
close all
pixelx = 1024;
pixely = 1024;
padx = 2*pixelx;
pady = 2*pixely;
sizex = 0.432;
sizey = 0.432;
mu = 0;
B_lin = 0;
x = linspace(-sizex, sizex, padx);
y = linspace(-sizey, sizey, pady);
[X,Y] = meshgrid(x,y);  %meshgrid for Input Beam
slmaperture = (X > -sizex/2 & X < sizex/2 & Y > -sizey/2 & Y <
 sizey/2);
x0=0; y0=0;             %center of CGH and Input Beam
tilt = 0;               %only if needed later
```

```
i_num = 15;             %number of iteration of GS and of SOMRAF
error = [];             %error array is empty for first
```

Input Variables

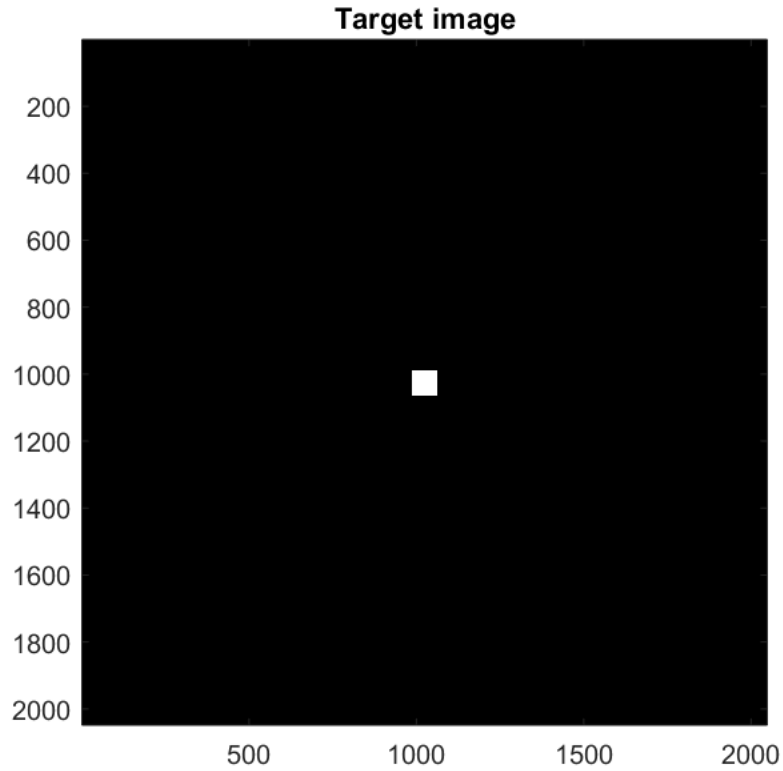
```
R = 200;
B_con = 0;
aspect_ratio = 1;
m = 0.98;
offset = 1;
kernel_waist = 100;
sigma = 0.74;                                       %beam waist in cm
 (need to be corrected)
```

Generate Gaussian Input Beam

```
A = 1;                                              %input amplitude
theta = ((X-x0).^2 + (Y-y0).^2)./(2*sigma^2);   %phase of Input beam
input = A*exp(-theta);                              %input amplitude for a
 given position
```

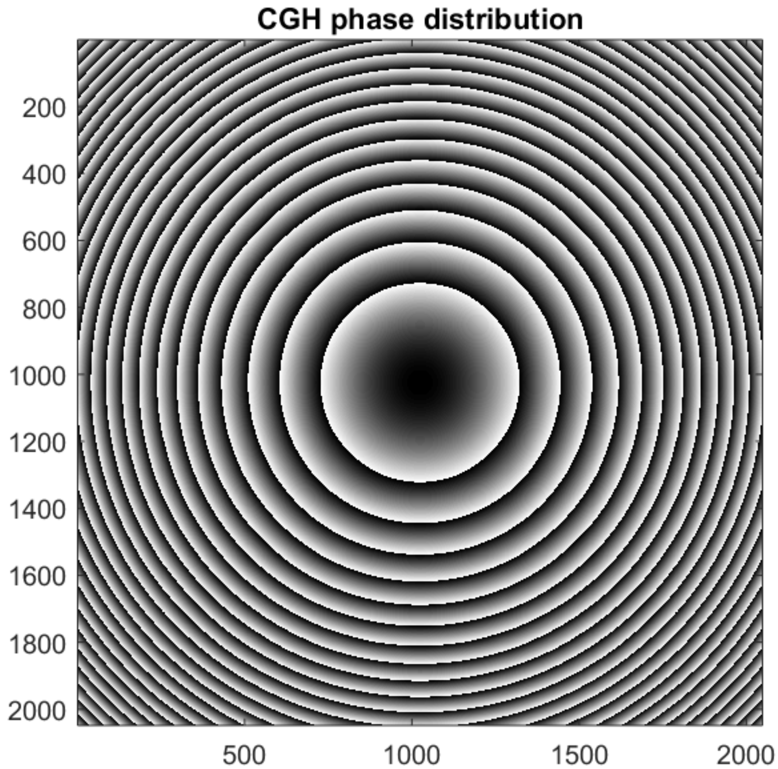
Target Image

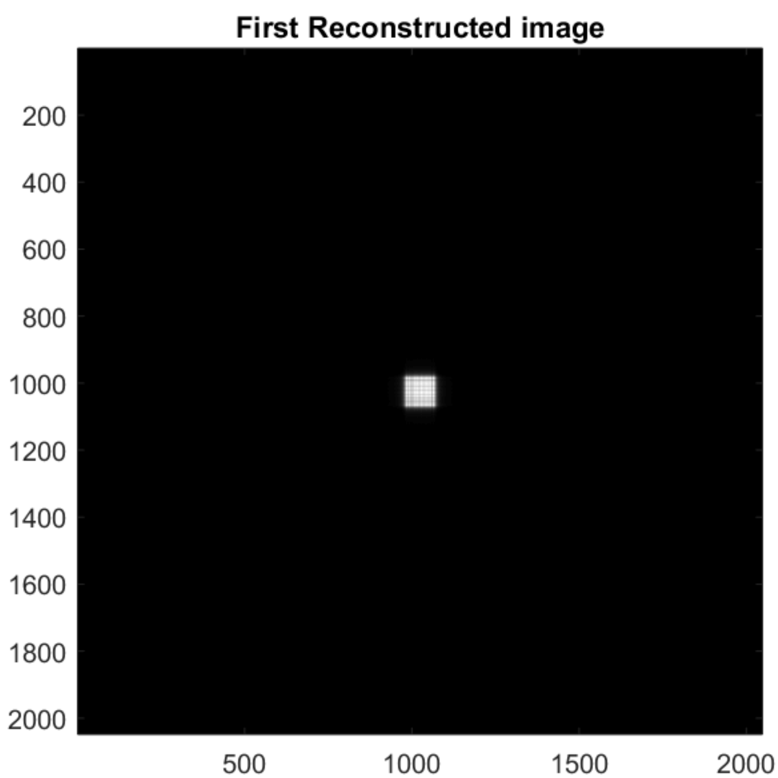
```
Target_Ori = rgb2gray(imread('square.bmp'));   %target image input
Target = double(Target_Ori);                      %changing the target into
 matrix of doubles with precision

 figure %Original Target Image
    imagesc(Target), axis image, colormap('gray');
    title('Target image')

SR_Ori = rgb2gray(imread('SR.bmp'));                %signal region
 input
threshold = 0.5;
SR = (double(SR_Ori) >= threshold);                 %change signal
 region into matrix of 1 and 0
NR = 1-SR;                                          %noise region =
 outside of signal region
MR = SR;                                            %measure region to
 measure the RMS error
N_m = nnz(MR);
Target_m = MR.*Target;
Target = sqrt(Target.^2 + offset^2);
```



Phase Initialization Step

```
%A = fftshift(ifft2(fftshift(Target)));  %performing GS initialization
 step, IFFT
% Notes: 2 times fftshift is used to shift the matrix (q1<->q3, q2<-
>q4)

alpha = aspect_ratio/(1+aspect_ratio);
A_quad = 4*R*(alpha*X.^2 + (1-alpha)*Y.^2);
A_lin = B_lin*(X*cos(mu) + Y*sin(mu));
A_con = B_con*sqrt(X.^2+Y.^2);
A = mod(A_quad + A_con + A_lin ,2*pi);
B = abs(input).*exp(1i*A);
C = fftshift(fft2(fftshift(B)));
figure %CGH Phase Distribution Result
      imagesc(abs(A)), axis image, colormap('gray');
      title('CGH phase distribution');
 %
figure %First Reconstructed Image
      imagesc(abs(C)), axis image, colormap('gray');
      title('First Reconstructed image')
```


CGH phase distribution
200
400
600
800
1000
1200
1400
1600
1800
2000
500
1000
1500
2000


First Reconstructed image
200
400
600
800
1000
1200
1400
1600
1800
2000
500
1000
1500
2000

Perform Gerchberg - Saxton (GS) Algorithm (check wikipedia for pseudo code)

```
for i=1:i_num
    D = abs(Target).*exp(1i*angle(C));
    A = fftshift(ifft2(fftshift(D)));
    B = abs(input).*exp(1i*angle(A));
    C = fftshift(fft2(fftshift(B)));
    %Error Calculation: Root Mean Squre Error of Measure Region
        C_m = MR.*C;
        error_cur = sqrt((1/N_m)*sum(sum(((abs(C_m)./
max(max(abs(C_m)))) - abs(Target_m)./max(max(abs(Target_m)))).^2 ) ));
        error = [error; error_cur];
end

for i=i_num+1 : 2*i_num
    D = (m*abs(Target).*SR + (1-m)*abs(C).*NR).*exp(1i*angle(C)); %the
 main line of MRAF algorithm
    A = fftshift(ifft2(fftshift(D)));
    B = abs(input).*exp(1i*angle(A));
    C = fftshift(fft2(fftshift(B)));
    %Error Calculation: Root Mean Squre Error of Measure Region
        C_m = MR.*C;
        error_cur = sqrt((1/N_m)*sum(sum(((abs(C_m)./
max(max(abs(C_m)))) - abs(Target_m)./max(max(abs(Target_m)))).^2 ) ));
        error = [error; error_cur];
end
```

Calibration Section by Dae Gwang

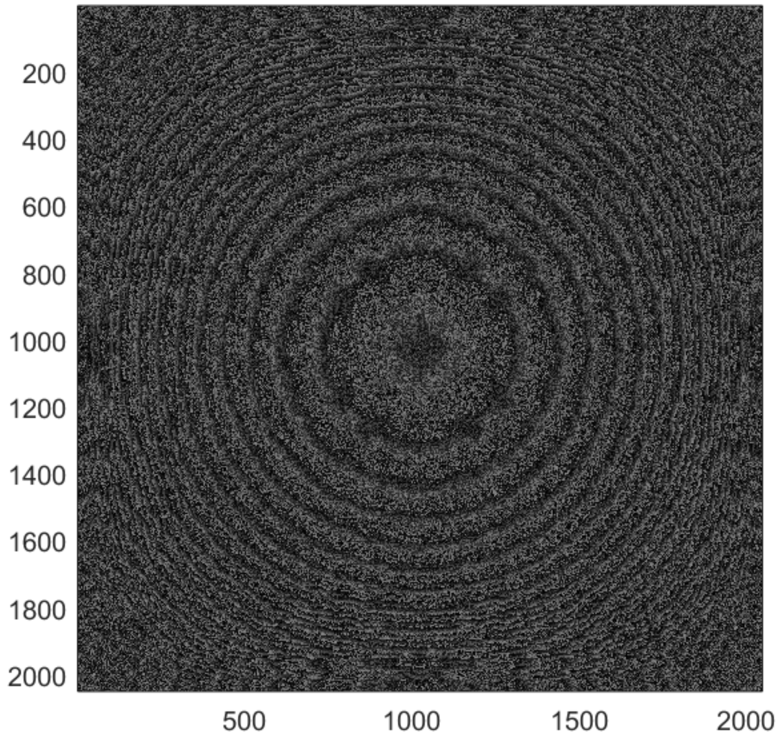
```
Crop=angle(A)+pi;    % change range, from -pi to pi into 0 to 2pi
aaaa=136;            % maximum gray level for 2pi phase shift (depends
 on SLM)
Crop=floor(aaaa.*Crop./(2.0*pi)); % converting the phase shift into
 gray level

% This line changes the black into the white
for j=1:pady
    for k=1:padx
        if Crop(j,k) == 0;
            Crop(j,k)=aaaa;
        end
    end
end

% This line is the main calibration section, which we got after
 experiment
for qi=1:pady
    for qj=1:padx
        k= Crop(qi,qj);
```

```
 Crop(qi,qj)=round(0.863*k-0.00596*(k)^2+0.00008035*k^3-0.000000238*k^4+0.00000000
    end
end
```

Figure of Calibrated CGH

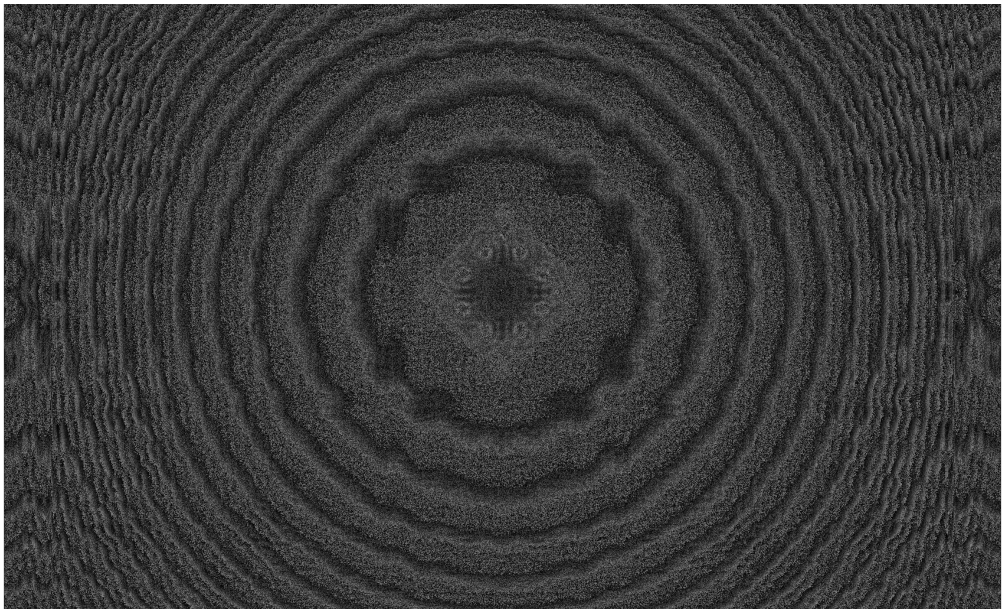
Crop=Crop';

```
figure
imagesc(Crop), axis image ,colormap('gray'), caxis([0,255]);
```



Setting the position, magnification, etc. of the CGH

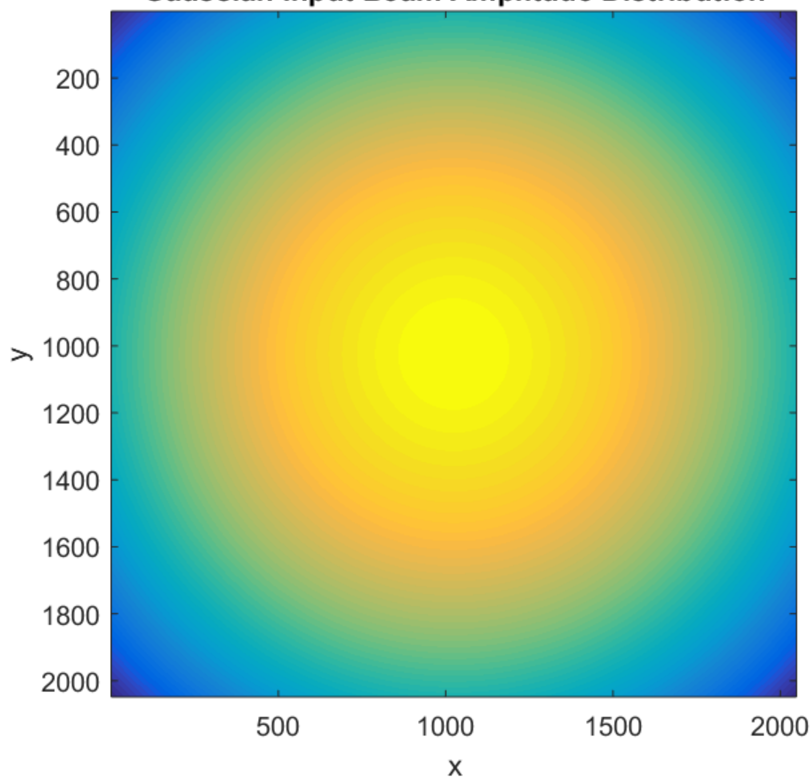
```
magni=1.65;

set(gcf, 'Units', 'Normalized', 'OuterPosition', [1 0.00 1 1]);
set(gca, 'Units', 'normalized','Position',[0. -0.3 1 magni]);
set(gcf, 'Toolbar', 'none', 'Menu', 'none','menubar','none','NumberTitle','off');
set(gca,'Yticklabel',[],'Xticklabel',[],'ytick',[],'xtick',[])
```



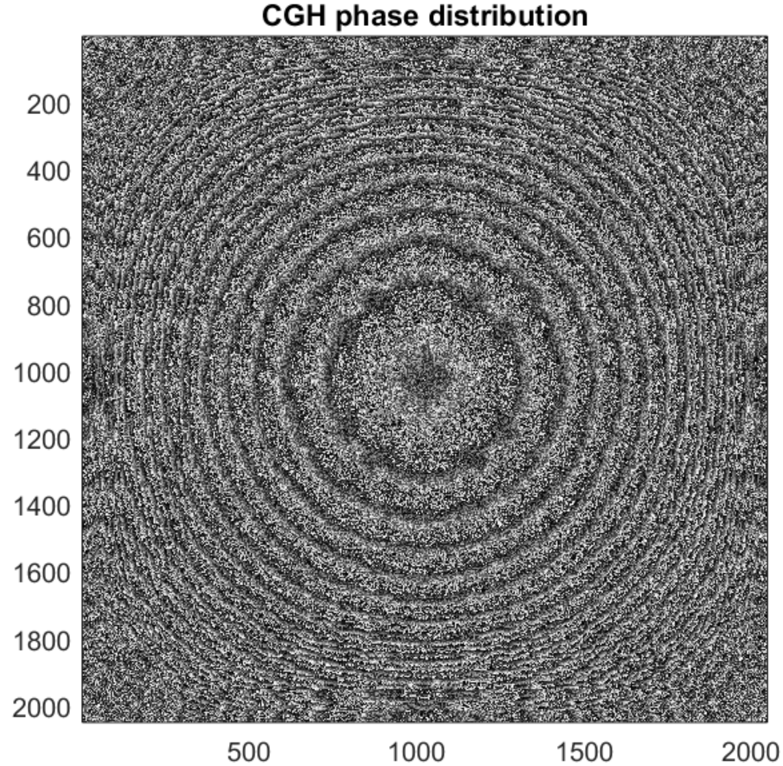
Show Result

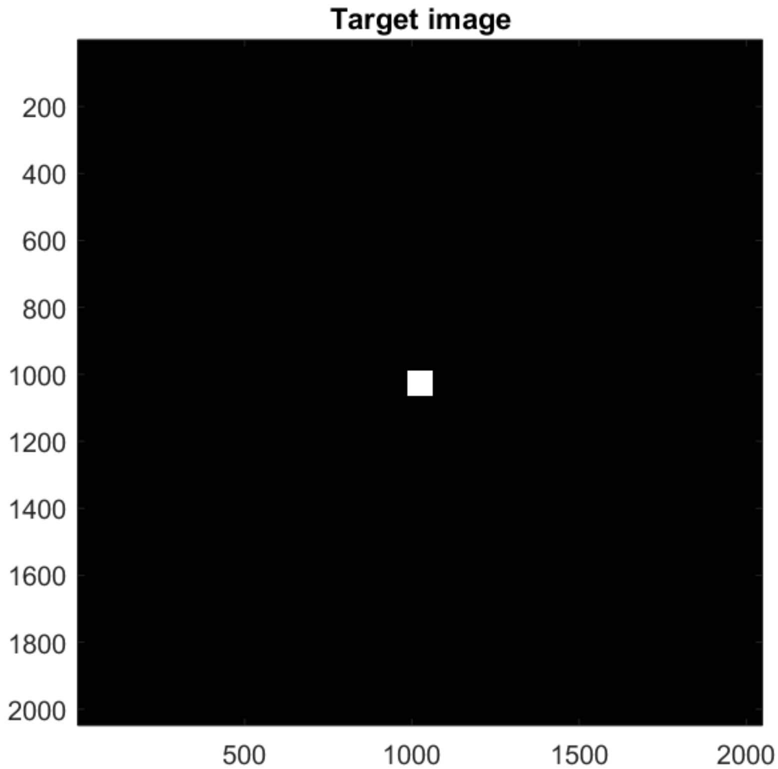
```
figure %Input Beam Distribution
    imagesc(input), axis image;
    title('Gaussian Input Beam Amplitude Distribution')
    xlabel('x')
    ylabel('y')

figure %CGH Phase Distribution Result
    imagesc(Crop), axis image, colormap('gray');
    title('CGH phase distribution');

figure %Original Target Image
    imagesc(Target./max(max(Target))),axis image, colormap('gray');
    title('Target image')

figure %Reconstructed Image
    imagesc(abs(C)./max(max(abs(C)))), axis image, colormap('gray');
    title('Reconstructed image');

figure %Error vs iteration
    i = 1:1:i;
    plot(i,(error'));
    %ylim([0 300])
    title('Error vs Iteration');
```

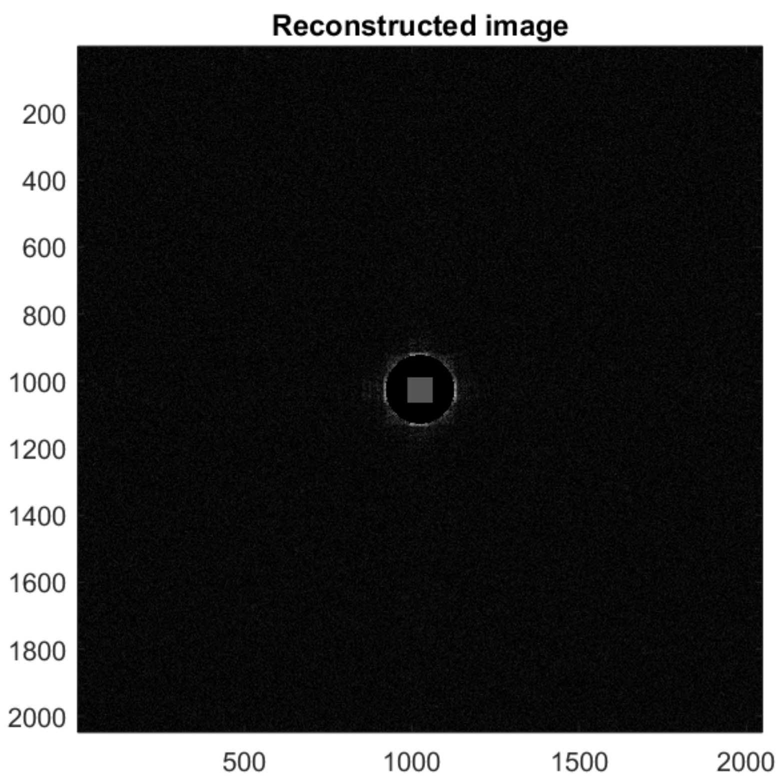
Gaussian Input Beam Amplitude Distribution

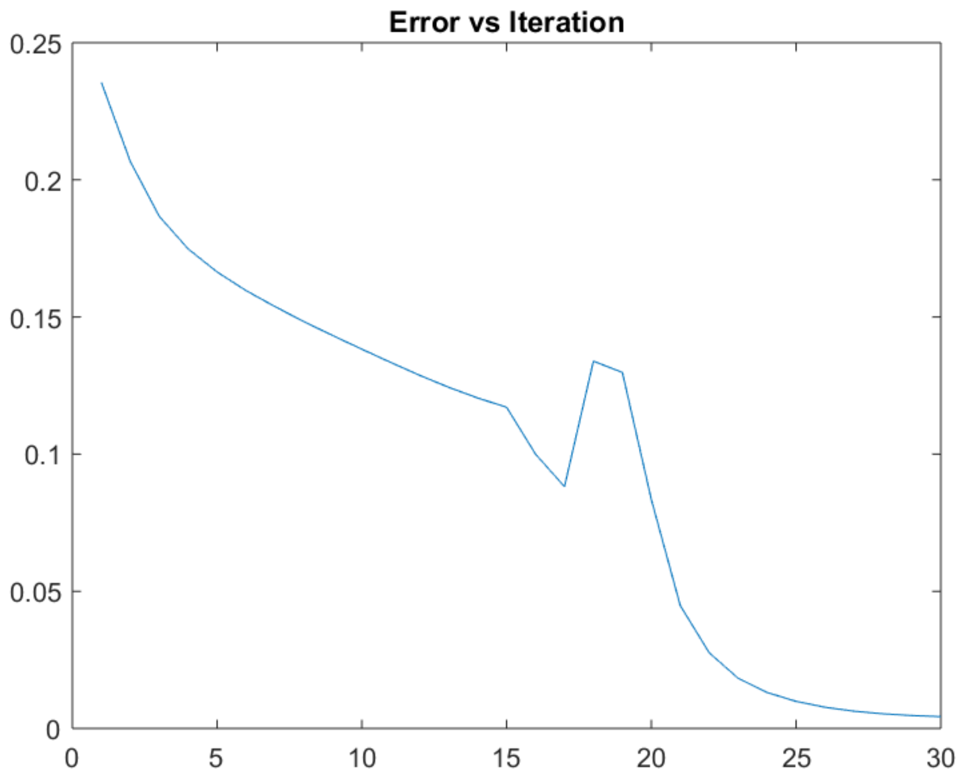


CGH phase distribution




Target image
200
400
600
800
1000
1200
1400
1600
1800
2000
500
1000
1500
2000


Reconstructed image
200
400
600
800
1000
1200
1400
1600
1800
2000
500
1000
1500
2000



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