Debevec Algorithm

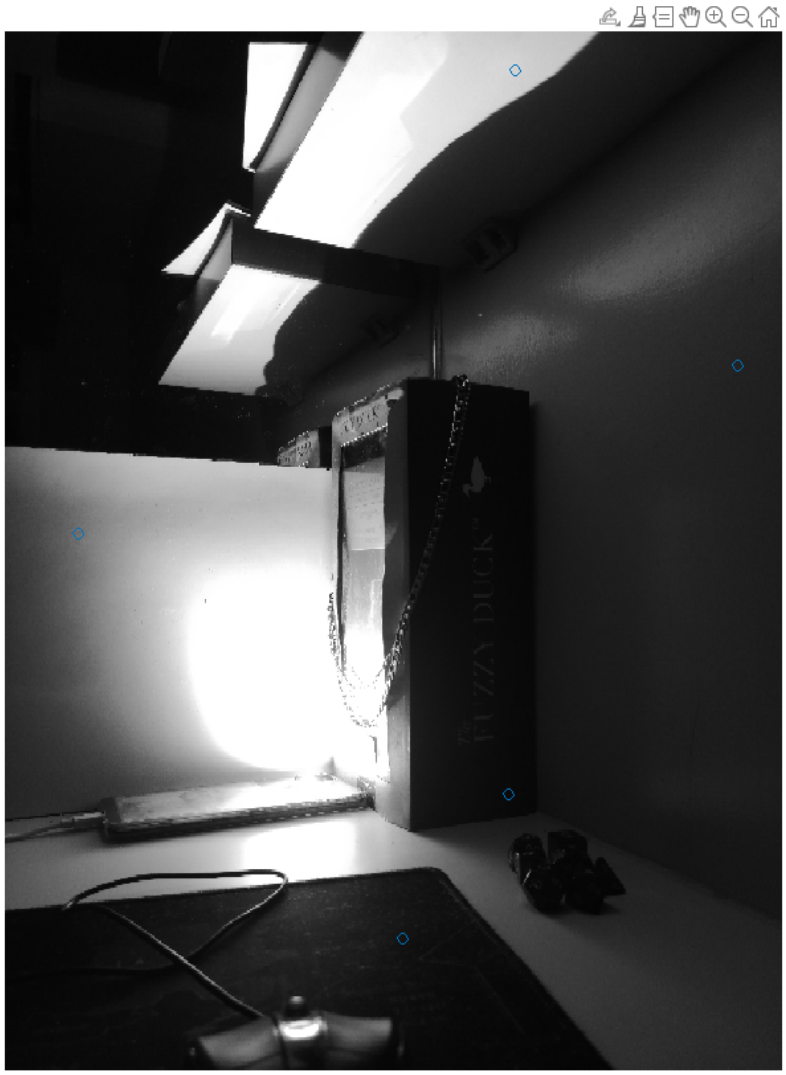
Plot response curve for exposure times $j = 15$ and pixel points $i = 5$

```
% Load Images
I2{1} = rgb2gray(imread('01-s4.jpg'));
I2{2} = rgb2gray(imread('02-s2.jpg'));
I2{3} = rgb2gray(imread('03-s1.jpg'));
I2{4} = rgb2gray(imread('s1-2.jpg'));
I2{5} = rgb2gray(imread('s1-4.jpg'));
I2{6} = rgb2gray(imread('s1-8.jpg'));
I2{7} = rgb2gray(imread('s1-15.jpg'));
I2{8} = rgb2gray(imread('s1-30.jpg'));
I2{9} = rgb2gray(imread('s1-60.jpg'));
I2{10} = rgb2gray(imread('s1-125.jpg'));
I2{11} = rgb2gray(imread('s1-250.jpg'));
I2{12} = rgb2gray(imread('s1-500.jpg'));
I2{13} = rgb2gray(imread('s1-1000.jpg'));
I2{14} = rgb2gray(imread('s1-2000.jpg'));
I2{15} = rgb2gray(imread('s1-4000.jpg'));

figure(1);
imshow(I2{6});
```

```
Warning: MATLAB has disabled some advanced graphics rendering features by switching to software OpenGL. For
more information, click here.
```

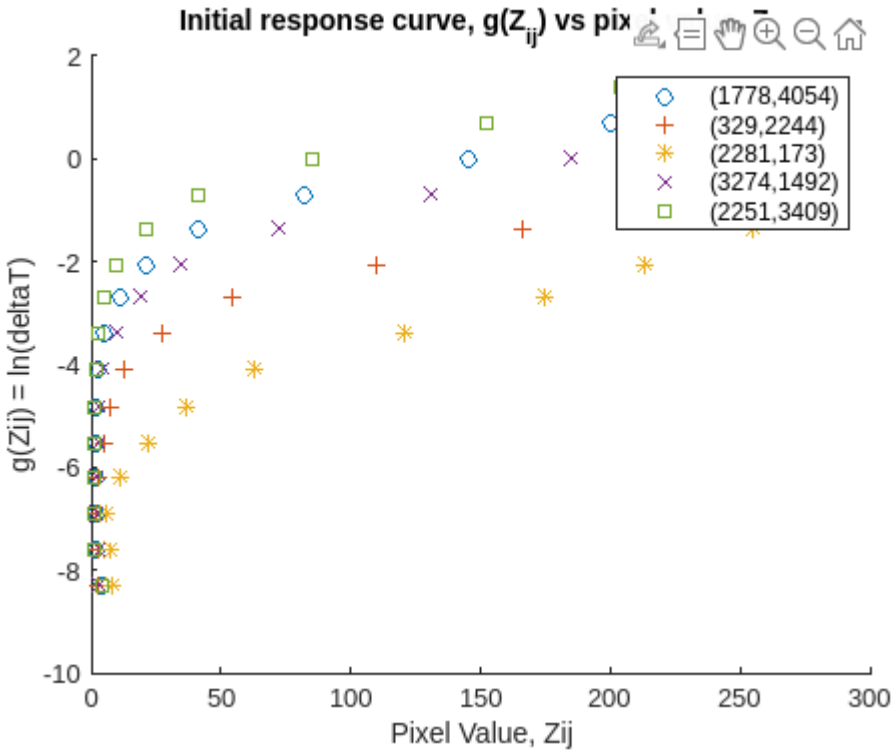
```
imwrite(I2{6},'gray6.jpg');
```

```
% Chosen 5 pixel points
% locsx=[1300,2269,2233,1370,406];
% locsy=[3202,1658,3480,3415,4272];

% Manual Choice
figure(2);
imshow(I2{6})
hold on
[locsx, locsy] = ginput(5);
locsx = round(locsx);
locsy = round(locsy);
scatter(locsx,locsy,"o");
hold off
```



```
% Set exposure times
deltaT  = [4;2;1;1/2;1/4;1/8;1/15;1/30;1/60;1/125;1/250;1/500;1/1000;1/2000;1/4000];
logDeltaT = log(deltaT);

% Setup variables
Z = zeros(numel(locsx),size(I2,2));
ni = numel(locsx);                      % number of pixel points, i
nj = size(I2,2);                        % number of exposure images, j
markers = ["o","+","*","x","square"];

% Obtain Zij for 5 points
for i=1:ni                      % iterate over pixel points
    pixVals = zeros(nj,1);
    exposures = zeros(nj,1);
    ix = locsx(i);
    iy = locsy(i);
```

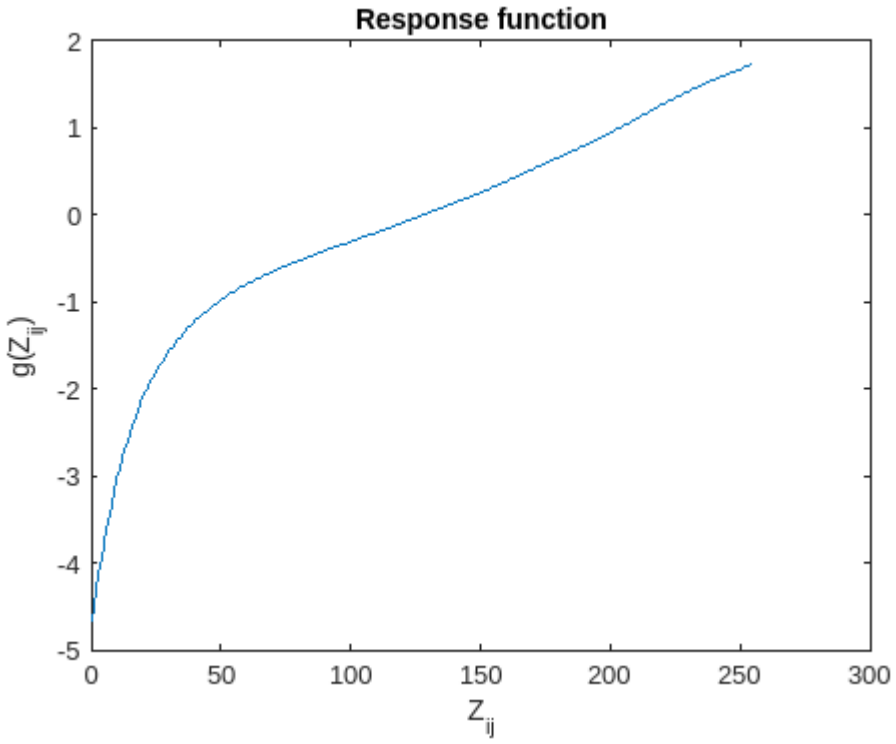
```
    for j=1:nj                  % iterate over exposures
        Z(i,j) = I2{j}(iy,ix);
        pixVals(j) = I2{j}(iy,ix);
        exposures(j) = logDeltaT(j);
    end
    figure(3);
    scatter(pixVals,exposures,markers(i),'DisplayName', ...
            sprintf('(%d,%d)',ix,iy))
    hold on
end
title('Initial response curve, g(Z_{ij}) vs pixel value, Z_{ij}')
xlabel('Pixel Value, Zij')
ylabel('g(Zij) = ln(deltaT)')
legend()
hold off
```



Solve for response function $g(Z_{ij})$

```
% Initialize weighing function
weight = zeros(256,1);
for i=1:256
    if i<=0.5*257
      weight(i) = i - 1;
    else
      weight(i) = 256 - i;
    end
end
```

```
% Initialize smoothing parameter
lambda = 50;

% Restructure logDeltaT for the g solver
logDeltaT1 = zeros(ni*nj,nj);
for j=1:nj
    logDeltaT1(:,j) = logDeltaT(j);
end

% Solve for the optimized g
[g, lE] = gMinimize(Z,logDeltaT1,lambda,weight);

% Plot response function
figure(4);
plot((0:255),g)
title('Response function')
xlabel('Z_{ij}')
ylabel('g(Z_{ij})')
```



Compute HDR Radiance Map

$$\ln E_i = \frac{\sum_{j=1}^{P} w(Z_{ij})(g(Z_{ij}) - \ln \Delta t_j)}{\sum_{j=1}^{P} w(Z_{ij})}$$

```
hdr = zeros(size(I2{1}));
sum = zeros(size(I2{1}));
for j=1:nj
    fprintf('Processing image %i of %i \n', j, nj);
    im = I2{j};                                 % Current image exposure
    wij = weight(im+1);                         % Calculate weights
    sum = sum + wij;                            % Add sum of weights
    numerator = g(im+1) - logDeltaT(j);         % Calculate summand
    hdr = hdr + (numerator.*wij);
end
```

```
Processing image 1 of 15
Processing image 2 of 15
Processing image 3 of 15
Processing image 4 of 15
Processing image 5 of 15
Processing image 6 of 15
Processing image 7 of 15
Processing image 8 of 15
Processing image 9 of 15
Processing image 10 of 15
Processing image 11 of 15
Processing image 12 of 15
Processing image 13 of 15
Processing image 14 of 15
Processing image 15 of 15
```

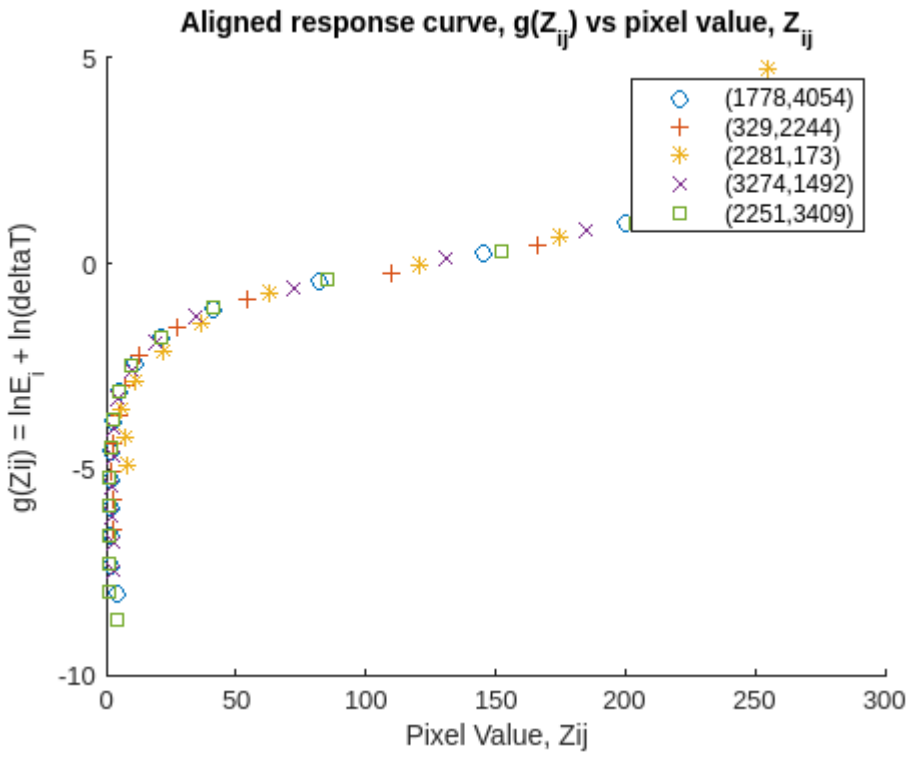
```
lnE = hdr./sum;
hdr = exp(lnE);
mono = tonemap(hdr);
imshow(mono)
```


```
imwrite(mono,'hdr-image.jpg');
```

Obtain aligned response function from sample points

```
% Obtain Zij for 5 points
for i=1:ni                      % iterate over pixel points
    pixVals = zeros(nj,1);
    exposures = zeros(nj,1);
    ix = locsx(i);
    iy = locsy(i);
    for j=1:nj                    % iterate over exposures
        Z(i,j) = I2{j}(iy,ix);
        pixVals(j) = I2{j}(iy,ix);
        exposures(j) = logDeltaT(j) + lnE(iy,ix);
    end
    figure(5);
    scatter(pixVals,exposures,markers(i),'DisplayName', ...
```

```
            sprintf('(%d,%d)',ix,iy))
    hold on
end
title('Aligned response curve, g(Z_{ij}) vs pixel value, Z_{ij}')
xlabel('Pixel Value, Zij')
ylabel('g(Zij) = lnE_i + ln(deltaT)')
legend()
hold off
```



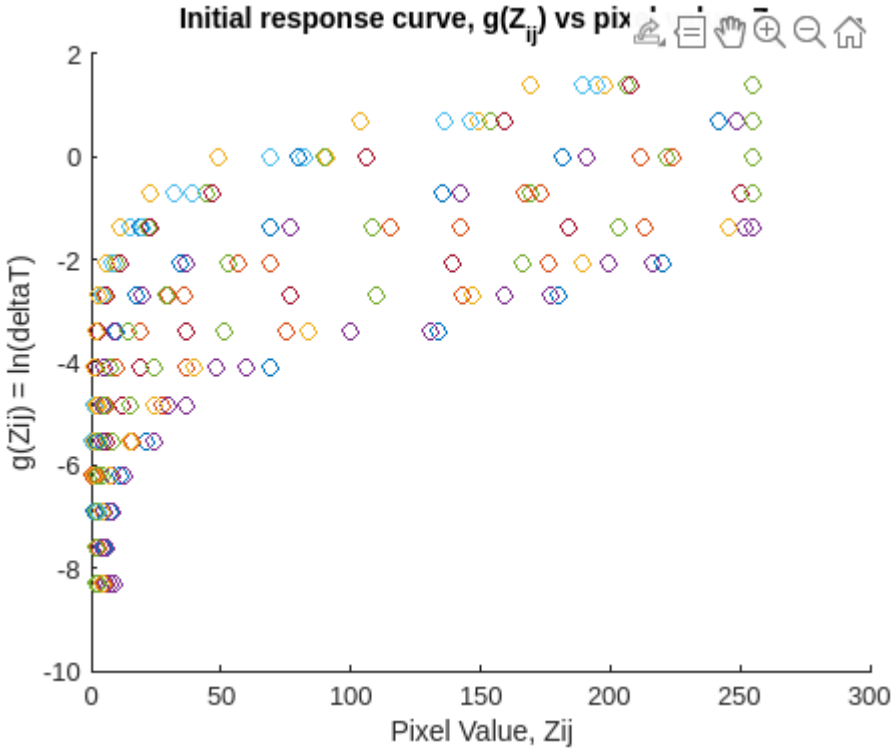
Following the number of measurement criterion

$$N > \frac{(Z_{max} - Z_{min})}{(P-1)} > \frac{255}{P-1} > \frac{255}{14} > 19$$

```
% Manual Choice
figure(2);
imshow(I2{6})
hold on
[locsx, locsy] = ginput(19);
locsx = round(locsx);
locsy = round(locsy);
scatter(locsx,locsy,"o");
hold off
```

```
% Set exposure times
deltaT  = [4;2;1;1/2;1/4;1/8;1/15;1/30;1/60;1/125;1/250;1/500;1/1000;1/2000;1/4000];
logDeltaT = log(deltaT);

% Setup variables
Z = zeros(numel(locsx),size(I2,2));
ni = numel(locsx);                      % number of pixel points, i
nj = size(I2,2);                        % number of exposure images, j
% markers = ["o","+","*","x","square"];

% Obtain Zij for 5 points
for i=1:ni                    % iterate over pixel points
    pixVals = zeros(nj,1);
    exposures = zeros(nj,1);
    ix = locsx(i);
```

```
    iy = locsy(i);
    for j=1:nj                  % iterate over exposures
        Z(i,j) = I2{j}(iy,ix);
        pixVals(j) = I2{j}(iy,ix);
        exposures(j) = logDeltaT(j);
    end
    figure(3);
    scatter(pixVals,exposures,"o")
    hold on
end
title('Initial response curve, g(Z_{ij}) vs pixel value, Z_{ij}')
xlabel('Pixel Value, Zij')
ylabel('g(Zij) = ln(deltaT)')
hold off
```




```
hdr = zeros(size(I2{1}));
sum = zeros(size(I2{1}));
for j=1:nj
    fprintf('Processing image %i of %i \n', j, nj);
    im = I2{j};                                 % Current image exposure
    wij = weight(im+1);                         % Calculate weights
    sum = sum + wij;                            % Add sum of weights
    numerator = g(im+1) - logDeltaT(j);         % Calculate summand
    hdr = hdr + (numerator.*wij);
end
```

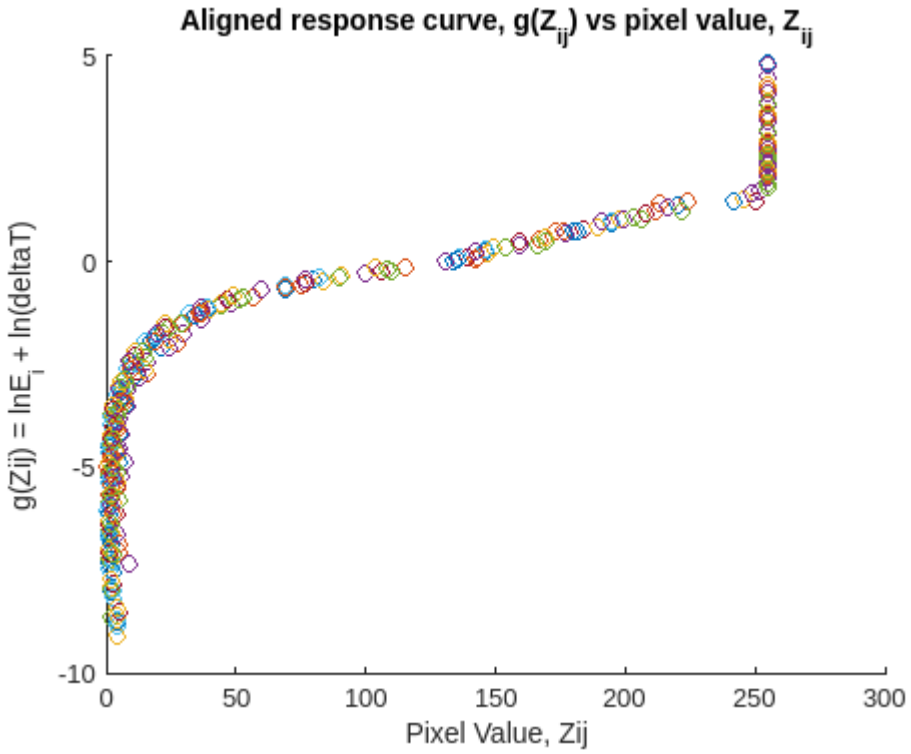
```
Processing image 1 of 15
Processing image 2 of 15
```

```
Processing image 3 of 15
Processing image 4 of 15
Processing image 5 of 15
Processing image 6 of 15
Processing image 7 of 15
Processing image 8 of 15
Processing image 9 of 15
Processing image 10 of 15
Processing image 11 of 15
Processing image 12 of 15
Processing image 13 of 15
Processing image 14 of 15
Processing image 15 of 15
```

```
lnE = hdr./sum;
hdr = exp(lnE);
mono = tonemap(hdr);
imshow(mono)
```


```
imwrite(mono,'hdr-image-19.jpg');
```

```
% Obtain Zij for 19 points
for i=1:ni                      % iterate over pixel points
    pixVals = zeros(nj,1);
    exposures = zeros(nj,1);
    ix = locsx(i);
    iy = locsy(i);
    for j=1:nj                   % iterate over exposures
        Z(i,j) = I2{j}(iy,ix);
        pixVals(j) = I2{j}(iy,ix);
        exposures(j) = logDeltaT(j) + lnE(iy,ix);
    end
    figure(5);
    scatter(pixVals,exposures,"o")
    hold on
end
title('Aligned response curve, g(Z_{ij}) vs pixel value, Z_{ij}')
xlabel('Pixel Value, Zij')
ylabel('g(Zij) = lnE_i + ln(deltaT)')
hold off
```




```
function [g,lE]=gMinimize(Z,logDeltaT1,lamda,weight)
    % Arguments:
    %
    % Z(i,j) is the pixel values of pixel location number i in image j
    % logDeltaT1(j) is the log delta t, or log shutter speed, for image j
    % lambda is lamdba, the constant that determines the amount of smoothness
```

```
    % weight(z) is the weighting function value for pixel value z
    %
    % Returns:
    %
    % g(z) is the log exposure corresponding to pixel value z
    % lE(i) is the log film irradiance at pixel location i

    n = 256;
    G = zeros(size(Z,1)*size(Z,2)+n+1,n+size(Z,1));
    b = zeros(size(G,1),1);
    start = 1;
    for i=1:size(Z,1)
        for j=1:size(Z,2)
            wij = weight(Z(i,j)+1);
            G(start,Z(i,j)+1) = wij;
            G(start,n+i) = -wij;
            b(start,1) = wij * logDeltaT1(i,j);
            start=start+1;
        end
    end
    G(start,129) = 1;
    start=start+1;
    for i=1:n-2
        % g''(z)= g(z-1) - 2g(z) + g(z+1)
        G(start,i)=lamda*weight(i+1);
        G(start,i+1)=-2*lamda*weight(i+1);
        G(start,i+2)=lamda*weight(i+1);
        start=start+1;
    end
    x = G\b;
    g = x(1:n);
    lE = 0;
    % lE = x(n+1,size(x,1));
end
```