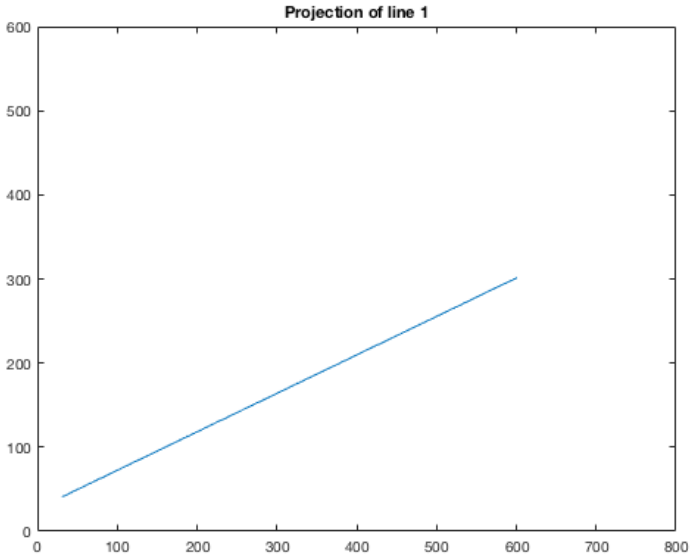
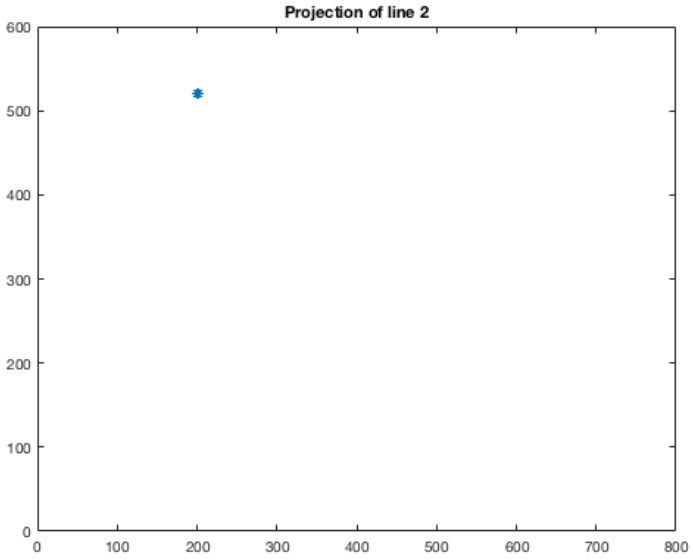
```
%=========================
%  Name:                hw2_1.m
%
%  Author:              Kairi Kozuma
%
%=========================

% a) Field of view
% Focal length
f = .004;

% Sensor dimensions
w = .0048;
h = .0036;

% Field of view in degrees
fov = (180 / pi) * 2 * [atan(w / (2 * f)), atan(h / (2 * f))];
fprintf('Field of view\n');
fprintf('Horizontal: %f degrees\nVertical: %f degrees\n\n',fov(1),fov(2));

% b) Lines to project
numpoint = 1000;
line1 = [linspace(-36.6,23.1,numpoint);linspace(-25.7,0.1,numpoint);linspace(66.0,77.0,numpoint)];
line2 = [linspace(-45.0,-81.0,numpoint);linspace(49.7,89.5,numpoint);linspace(150.0,270.0,numpoint)];

line1proj = camera(line1);
line2proj = camera(line2);

figure(1);
plot(line1proj(1,:), line1proj(2,:));
axis([0, 800, 0, 600]);
title('Projection of line 1');

figure(2);
plot(line2proj(1,:), line2proj(2,:), '-*');
axis([0, 800, 0, 600]);
title('Projection of line 2');

fprintf('Line 1 collapses onto a single point in the projection, while line 2 appears to be a line\n');

% c) Plot squares
s1pt = 1000; % Number of points for linspace
s1w = 7.5; % Square 1 width

square1 = makeSquare([-30.0, -15.0, 100.0],7.5,1000);
square2 = makeSquare([0.0, 27.6, 160.0],12,1000);

square1proj = camera(square1);
square2proj = camera(square2);

figure(3);
plot(square1proj(1,:), square1proj(2,:));
title('Projection of square 1');
axis('equal');

figure(4);
plot(square2proj(1,:), square2proj(2,:));
title('Projection of square 2');
axis('equal');

% Relative size
fprintf('The two squares have the same relative size in the projection');

%=============================== makeSquare ==============================
%
%  Creates vector of squares with same z coordinate from bottom-left point
%  and width of square
%
%
%  function coords = makeSquare(lbcoords, width, n)
%
%  Input:
%    lbcoords   - Coordinates of bottom left point, [x,y,z]
%    width      - Width of square
%    n          - number of points per side
%
%  Output:
%    coords     - coordinates of all points on the square
%
%=============================== makeSquare ==============================
```

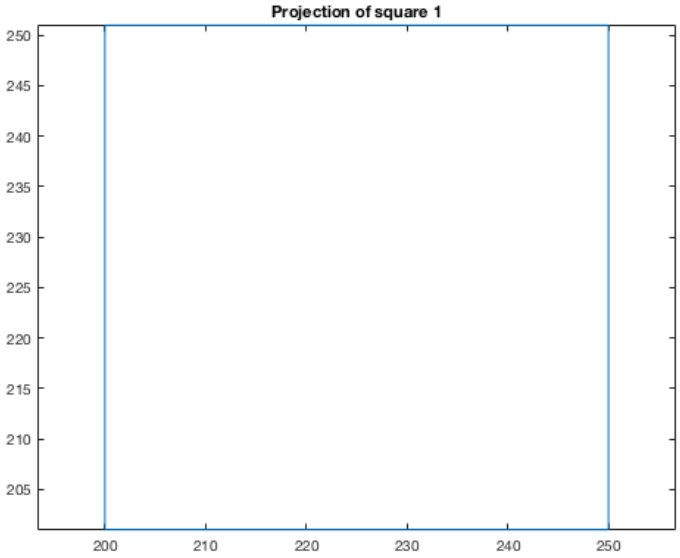
```
function coords = makeSquare(lbcoords, width, n)

side1 = [linspace(lbcoords(1),lbcoords(1)+width,n);linspace(lbcoords(2),lbcoords(2),n);linspace(lbcoords(3),lbcoords(3),n)];
side2 = [linspace(lbcoords(1),lbcoords(1),n);linspace(lbcoords(2),lbcoords(2)+width,n);linspace(lbcoords(3),lbcoords(3),n)];
side3 = [linspace(lbcoords(1)+width,lbcoords(1)+width,n);linspace(lbcoords(2),lbcoords(2)+width,n);linspace(lbcoords(3),lbcoords(3),n)];
side4 = [linspace(lbcoords(1),lbcoords(1)+width,n);linspace(lbcoords(2)+width,lbcoords(2)+width,n);linspace(lbcoords(3),lbcoords(3),n)];

coords = [side1, side2, side4, side3];
end

%================================ camera ================================
%
%  Implements the camera projection equations to a CCD-type sensor.
%  Takes in the real world coordinates in meters of a point and returns
%  the image coordinate location in pixels of the point.
%
%
%  function icoords = camera(wcoords)
%
%  Input:
%    wcoords    -The world coordinates of a point in meters as a column
%                  vector.
%
%  Output:
%    icoords    -The image coordinates of the point in pixels as a
%                  column vector.
%
%
%  If done properly, then passing a matrix of column vectors should perform
%  the projection equations for all of the associated vectors and return
%  a matrix of column vectors representing the projected 3D points.
%  This requires some savviness with Matlab (using .* and ./).
%
%================================ camera ================================

%
%  Name:        camera.m
%
%  Author:      Patricio A. Vela, pvela@ece.gatech.edu
%
%  Created:             2006/01/19
%  Modified:    2013/01/17
%
%================================ camera ================================

function icoords = camera(wcoords)

[M, N] = size(wcoords);

if (M ~= 3)
  error('Input needs to be 3D column vector(s).');
end

xvals = wcoords(1,:);
yvals = wcoords(2,:);
zvals = wcoords(3,:);

% Focal length
f = .004;

% Sensor dimensions
w = .0048;
h = .0036;

% Sensor resolution
W = 800;
H = 600;

% Pixel size
dr1 = w / W;
dr2 = h / H;

% View-centered projection equations
r1 = f * xvals ./ zvals;
r2 = f * yvals ./ zvals;

% Sensor array equations
R1 = ceil(r1./dr1) + (W / 2);
R2 = ceil(r2./dr2) + (H / 2);

% Camera coordinates
icoords = [R1; R2];
```

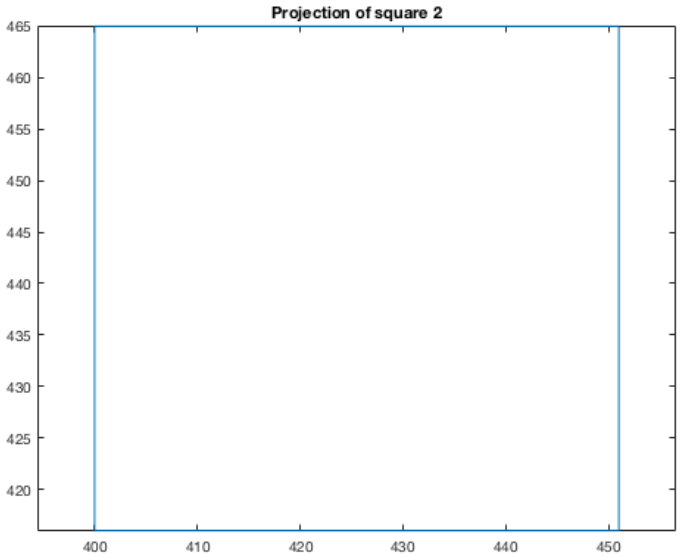
```
end
```

```
Field of view
Horizontal: 61.927513 degrees
Vertical: 48.455491 degrees

Line 1 collapses onto a single point in the projection, while line 2 appears to be a line
The two squares have the same relative size in the projection
```









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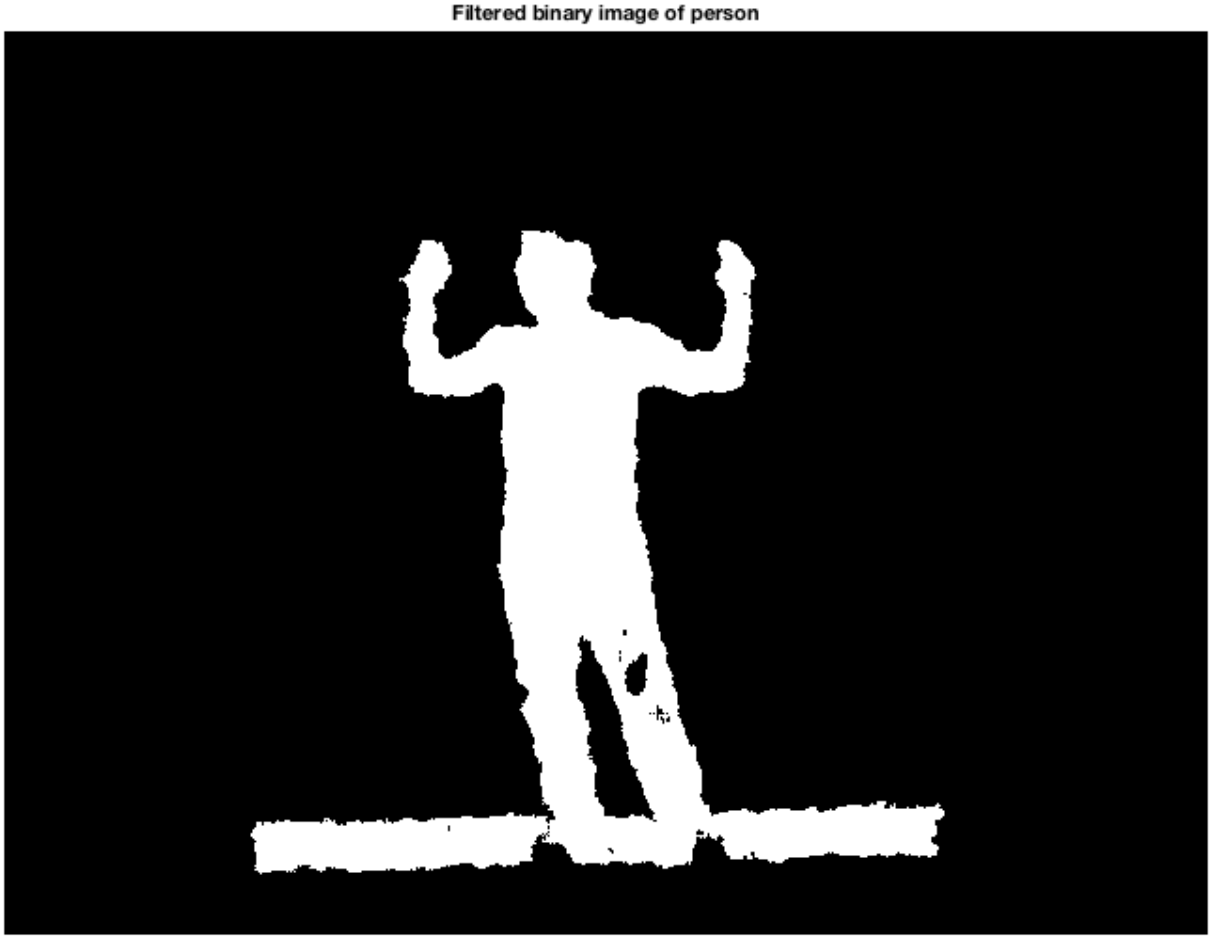
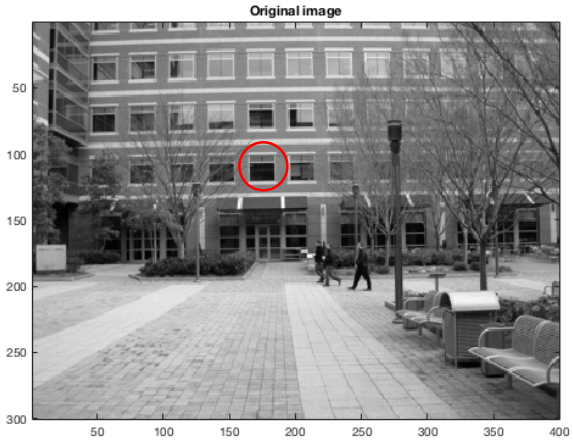
```
%==========================
%  Name:                hw2_2.m
%
%  Author:              Kairi Kozuma
%
%==========================

% Histogram used to choose threshold
% hist(reshape(double(range), 1, 480*640), 2200);

% Set threshold values
lowerThresh = 959;
upperThresh = 978;


% Apply threshold to range image
binImage = (range > lowerThresh) & (range < upperThresh);

% bwselect to pick out person
binPerson = bwselect(binImage, 304, 212);

figure(1);
imshow(binPerson);
title('Filtered binary image of person');
```



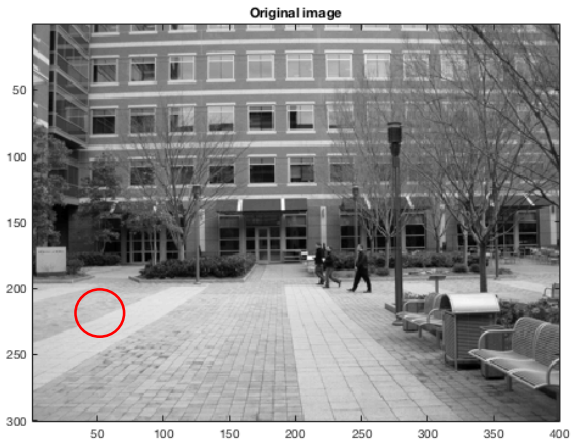
Problem 3.

A confusion matrix is used to measure performance of a classification algorithm. The four basic types of answers are True Positives (TP), True Negatives (TN), False Positives (FP), and False Negatives. TP are true values that are correctly identified as true, while TN are false values that are correctly identified as false. FP are values that are predicted true, but are actually false. Similarly, FN are values that are predicted false, but are actually true.

1) TP includes edges that are correctly identified from the original image. In the filtered image below, the area circled in red correctly identifies the window edges from the original black and white image.



2) FN are edges from the original image that were not detected successfully in the filtered image. The area circled in red identifies the sidewalk edge that was not detected in the two-threshold filter.

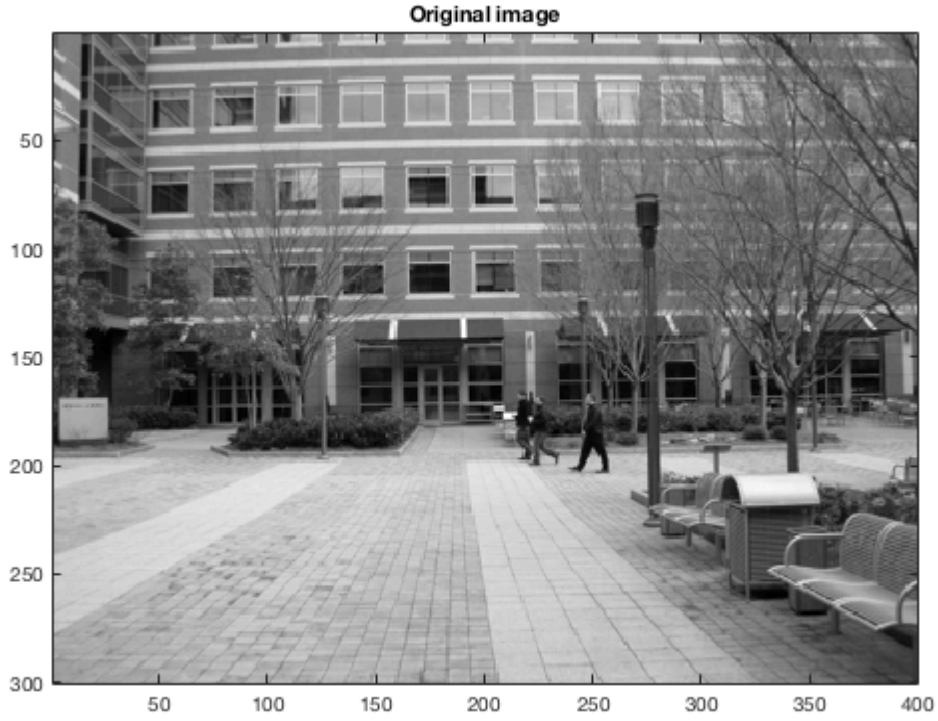


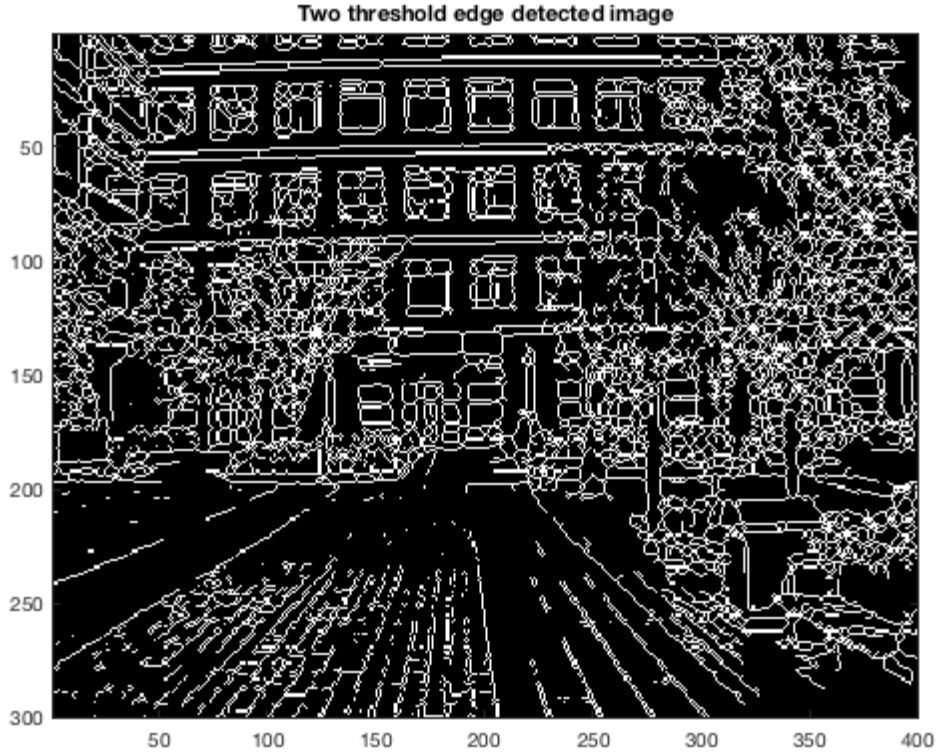
```
%==========================
%  Name:                hw2_4.m
%
%  Author:              Kairi Kozuma
%
%==========================

%============================ hysteresisEdges ============================
%
%  script hysteresisEdges.m
%
%
%  Loads the edgethresh.mat Matlab file (make sure to have it in your
%  path or your current directory) and then applies hystersis-based
%  edge finding to identify which parts of the image reflect edge-like
%  structures.
%
%============================ hysteresisEdges ============================

%
%  Name:                hysteresisEdges.m
%
%  Author:              Patricio A. Vela,                       pvela@gatech.edu
%
%  Created:             2014/01/18
%  Modified:    2014/01/18
%
%============================ hysteresisEdges ============================

%--[1] Load the edgethresh Matlab file.
load('edgethresh.mat');
I = double(I);          % Convert to double or crazy stuff happens.

highT = 145;
lowT = 120;

fprintf('High threshold: %d\nLow threshold: %d\n', highT, lowT);

%--[2] Run the edge finding function to get a binary image.
detect = edgefind(I, highT, lowT);

%--[4] Plot the image and also visualize the detected edge locations.
figure(1);
  imagesc(I);
  colormap('gray');
  title('Original image');
  axis image;

figure(2);
  imagesc(detect);
  colormap('gray');
  title('Two threshold edge detected image');

fprintf('The results are better than using a single\n');
fprintf('threshold, since two thresholds captures more edges that have lower\n');
fprintf('contrast with its environment. For example, the image obtained from\n');
fprintf('two thresholds shows more of edges in the trees and sidewalk, while\n');
fprintf('the edge detection with one threshold does not capture them.');
```

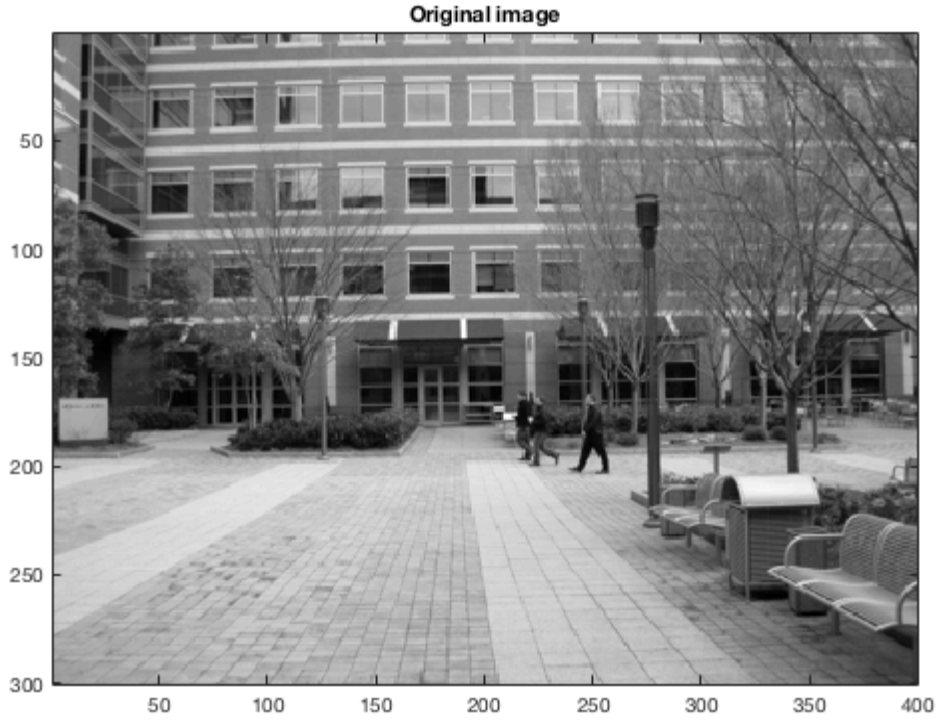
```
%================================ edgefind ================================
%
%  edgeIm = edgefind(I, highT, lowT)
%
%  INPUTS:
%    I                  - the image (should be double!)
%    highT              - the upper threshold.
%    lowT       - the lower threshold.
%
%  OUTPUTS:
%    escore             - the edge score.
%
%================================ edgefind ================================

%
%  Name:                edgefind.m
%
%  Author:              Patricio A. Vela,                       pvela@gatech.edu
%
%  Created:             2014/01/17
%  Modified:    2014/01/17
%
%================================ edgefind ================================
function [detected] = edgefind(I, highT, lowT)


%-- Compute the gradient of the image.
cdx = [-1 0 1]/2;
cdy = cdx';

dIdx = imfilter(I, cdx, 'replicate');
dIdy = imfilter(I, cdy, 'replicate');

%-- Compute the edge score (sum of squares of derivatives).
score = dIdx.^2 + dIdy.^2;

%--Perform hysteresis with the upper and lower score thresholds.
highDetect = score > highT ; % Apply the upper threshold first.
[i, j] = find(highDetect);  % Using find, get indices of detected points.

lowDetect  = score > lowT;  % Apply the lower threshold second.

detected = bwselect(lowDetect, i, j);
                      % Using bwselect with the detected points on the
                      % low detection binary image, get more candidates.

detected = bwmorph(detected, 'thin', inf);
                      % Apply some thinning to get skinny edge lines.


end
```

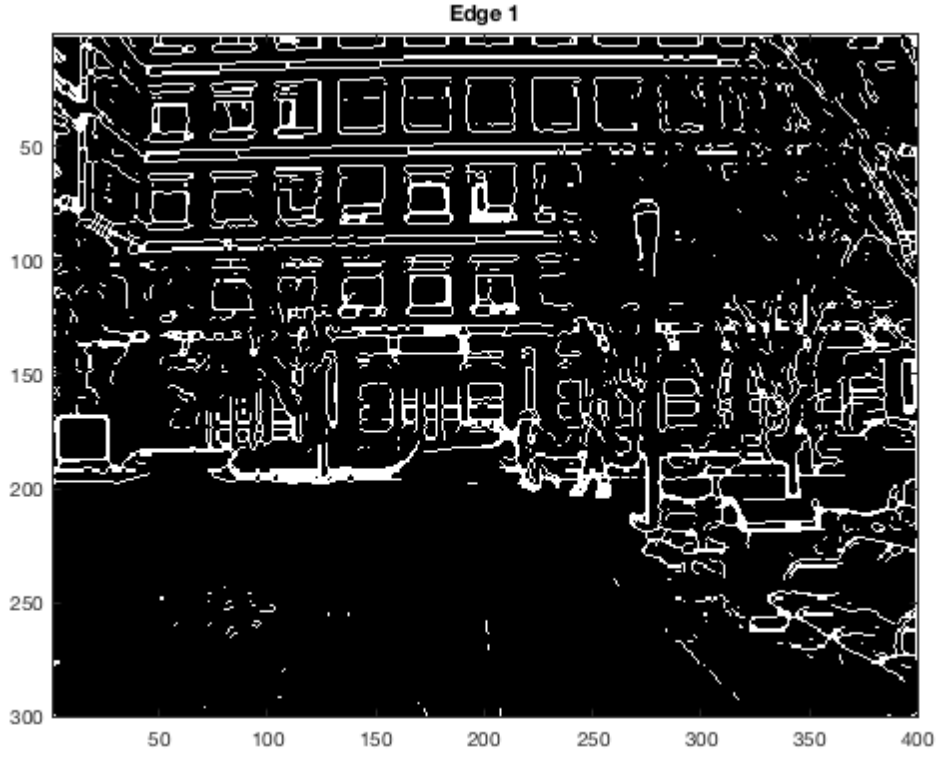
```
High threshold: 145
Low threshold: 120
Warning: Ignoring out-of-range input coordinates.
The results are better than using a single
threshold, since two thresholds captures more edges that have lower
contrast with its environment. For example, the image obtained from
```

two thresholds shows more of edges in the trees and sidewalk, while the edge detection with one threshold does not capture them.






Original image
50
100
150
200
250
300
50
100
150
200
250
300
350
400


Edge 1
50
100
150
200
250
300
50
100
150
200
250
300
350
400