01 Matlab Code

1. Hough.m

```
function [h, theta, rho] = hough(f, dtheta, drho)
%HOUGH Hough transform.
%   [H, THETA, RHO] = HOUGH(F, DTHETA, DRHO) computes the Hough
%   transform of the image F.  DTHETA specifies the spacing (in
%   degrees) of the Hough transform bins along the theta axis.  DRHO
%   specifies the spacing of the Hough transform bins along the rho
%   axis.  H is the Hough transform matrix.  It is NRHO-by-NTHETA,
%   where NRHO = 2*ceil(norm(size(F))/DRHO) - 1, and NTHETA =
%   2*ceil(90/DTHETA).  Note that if 90/DTHETA is not an integer, the
%   actual angle spacing will be 90 / ceil(90/DTHETA).
%
%   THETA is an NTHETA-element vector containing the angle (in
%   degrees) corresponding to each column of H.  RHO is an
%   NRHO-element vector containing the value of rho corresponding to
%   each row of H.
%
%   [H, THETA, RHO] = HOUGH(F) computes the Hough transform using
%   DTHETA = 1 and DRHO = 1.

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if nargin < 3
   drho = 1;
end
if nargin < 2
   dtheta = 1;
end

f = double(f);
[M,N] = size(f);
theta = linspace(-90, 0, ceil(90/dtheta) + 1);
theta = [theta -fliplr(theta(2:end - 1))];
ntheta = length(theta);

D = sqrt((M - 1)^2 + (N - 1)^2);
q = ceil(D/drho);
nrho = 2*q - 1;
rho = linspace(-q*drho, q*drho, nrho);

[x, y, val] = find(f);
x = x - 1;  y = y - 1;

% Initialize output.
h = zeros(nrho, length(theta));

% To avoid excessive memory usage, process 1000 nonzero pixel
% values at a time.
```

```
for k = 1:ceil(length(val)/1000)
   first = (k - 1)*1000 + 1;
   last  = min(first+999, length(x));

   x_matrix     = repmat(x(first:last), 1, ntheta);
   y_matrix     = repmat(y(first:last), 1, ntheta);
   val_matrix   = repmat(val(first:last), 1, ntheta);
   theta_matrix = repmat(theta, size(x_matrix, 1), 1)*pi/180;

   rho_matrix = x_matrix.*cos(theta_matrix) + ...
       y_matrix.*sin(theta_matrix);
   slope = (nrho - 1)/(rho(end) - rho(1));
   rho_bin_index = round(slope*(rho_matrix - rho(1)) + 1);

   theta_bin_index = repmat(1:ntheta, size(x_matrix, 1), 1);

   % Take advantage of the fact that the SPARSE function, which
   % constructs a sparse matrix, accumulates values when input
   % indices are repeated.  That¡¯s the behavior we want for the
   % Hough transform.  We want the output to be a full (nonsparse)
   % matrix, however, so we call function FULL on the output of
   % SPARSE.
   h = h + full(sparse(rho_bin_index(:), theta_bin_index(:), ...
                   val_matrix(:), nrho, ntheta));
end
```

2. Houghpeaks.m

```
function [r, c, hnew] = houghpeaks(h, numpeaks, threshold, nhood)
%HOUGHPEAKS Detect peaks in Hough transform.
%   [R, C, HNEW] = HOUGHPEAKS(H, NUMPEAKS, THRESHOLD, NHOOD) detects
%   peaks in the Hough transform matrix H.  NUMPEAKS specifies the
%   maximum number of peak locations to look for.  Values of H below
%   THRESHOLD will not be considered to be peaks.  NHOOD is a
%   two-element vector specifying the size of the suppression
%   neighborhood.  This is the neighborhood around each peak that is
%   set to zero after the peak is identified.  The elements of NHOOD
%   must be positive, odd integers.  R and C are the row and column
%   coordinates of the identified peaks.  HNEW is the Hough transform
%   with peak neighborhood suppressed.
%
%   If NHOOD is omitted, it defaults to the smallest odd values >=
%   size(H)/50.  If THRESHOLD is omitted, it defaults to
%   0.5*max(H(:)).  If NUMPEAKS is omitted, it defaults to 1.

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if nargin < 4
   nhood = size(h)/50;
   % Make sure the neighborhood size is odd.
   nhood = max(2*ceil(nhood/2) + 1, 1);
end
```

```
if nargin < 3
   threshold = 0.5 * max(h(:));
end
if nargin < 2
   numpeaks = 1;
end

done = false;
hnew = h; r = []; c = [];
while ~done
   [p, q] = find(hnew == max(hnew(:)));
   p = p(1); q = q(1);
   if hnew(p, q) >= threshold
      r(end + 1) = p; c(end + 1) = q;

      % Suppress this maximum and its close neighbors.
      p1 = p - (nhood(1) - 1)/2; p2 = p + (nhood(1) - 1)/2;
      q1 = q - (nhood(2) - 1)/2; q2 = q + (nhood(2) - 1)/2;
      [pp, qq] = ndgrid(p1:p2,q1:q2);
      pp = pp(:); qq = qq(:);

      % Throw away neighbor coordinates that are out of bounds in
      % the rho direction.
      badrho = find((pp < 1) | (pp > size(h, 1)));
      pp(badrho) = []; qq(badrho) = [];

      % For coordinates that are out of bounds in the theta
      % direction, we want to consider that H is antisymmetric
      % along the rho axis for theta = +/- 90 degrees.
      theta_too_low = find(qq < 1);
      qq(theta_too_low) = size(h, 2) + qq(theta_too_low);
      pp(theta_too_low) = size(h, 1) - pp(theta_too_low) + 1;
      theta_too_high = find(qq > size(h, 2));
      qq(theta_too_high) = qq(theta_too_high) - size(h, 2);
      pp(theta_too_high) = size(h, 1) - pp(theta_too_high) + 1;

      % Convert to linear indices to zero out all the values.
      hnew(sub2ind(size(hnew), pp, qq)) = 0;

      done = length(r) == numpeaks;
   else
      done = true;
   end
end
```

3. Houghpixels.m

```
function [r, c] = houghpixels(f, theta, rho, rbin, cbin)
%HOUGHPIXELS Compute image pixels belonging to Hough transform bin.
%   [R, C] = HOUGHPIXELS(F, THETA, RHO, RBIN, CBIN) computes the
%   row-column indices (R, C) for nonzero pixels in image F that map
%   to a particular Hough transform bin, (RBIN, CBIN).  RBIN and CBIN
%   are scalars indicating the row-column bin location in the Hough
%   transform matrix returned by function HOUGH.  THETA and RHO are
%   the second and third output arguments from the HOUGH function.

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[x, y, val] = find(f);
x = x - 1; y = y - 1;

theta_c = theta(cbin) * pi / 180;
rho_xy = x*cos(theta_c) + y*sin(theta_c);
nrho = length(rho);
slope = (nrho - 1)/(rho(end) - rho(1));
rho_bin_index = round(slope*(rho_xy - rho(1)) + 1);

idx = find(rho_bin_index == rbin);

r = x(idx) + 1; c = y(idx) + 1;
```

4. Houghlines.m

```
function lines = houghlines(f,theta,rho,rr,cc,fillgap,minlength)
%HOUGHLINES Extract line segments based on the Hough transform.
%   LINES = HOUGHLINES(F, THETA, RHO, RR, CC, FILLGAP, MINLENGTH)
%   extracts line segments in the image F associated with particular
%   bins in a Hough transform.  THETA and RHO are vectors returned by
%   function HOUGH.  Vectors RR and CC specify the rows and columns
%   of the Hough transform bins to use in searching for line
%   segments.  If HOUGHLINES finds two line segments associated with
%   the same Hough transform bin that are separated by less than
%   FILLGAP pixels, HOUGHLINES merges them into a single line
%   segment.  FILLGAP defaults to 20 if omitted.  Merged line
%   segments less than MINLENGTH pixels long are discarded.
%   MINLENGTH defaults to 40 if omitted.
%
%   LINES is a structure array whose length equals the number of
%   merged line segments found.  Each element of the structure array
%   has these fields:
%
```

```
%     point1    End-point of the line segment; two-element vector
%     point2    End-point of the line segment; two-element vector
%     length    Distance between point1 and point2
%     theta     Angle (in degrees) of the Hough transform bin
%     rho       Rho-axis position of the Hough transform bin

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if nargin < 6
   fillgap = 20;
end
if nargin < 7
   minlength = 40;
end

numlines = 0; lines = struct;
for k = 1:length(rr)
   rbin = rr(k); cbin = cc(k);

   % Get all pixels associated with Hough transform cell.
   [r, c] = houghpixels(f, theta, rho, rbin, cbin);
   if isempty(r)
      continue
   end

   % Rotate the pixel locations about (1,1) so that they lie
   % approximately along a vertical line.
   omega = (90 - theta(cbin)) * pi / 180;
   T = [cos(omega) sin(omega); -sin(omega) cos(omega)];
   xy = [r - 1  c - 1] * T;
   x = sort(xy(:,1));

   % Find the gaps larger than the threshold.
   diff_x = [diff(x); Inf];
   idx = [0; find(diff_x > fillgap)];
   for p = 1:length(idx) - 1
      x1 = x(idx(p) + 1); x2 = x(idx(p + 1));
      linelength = x2 - x1;
      if linelength >= minlength
         point1 = [x1 rho(rbin)]; point2 = [x2 rho(rbin)];
         % Rotate the end-point locations back to the original
         % angle.
         Tinv = inv(T);
         point1 = point1 * Tinv; point2 = point2 * Tinv;

         numlines = numlines + 1;
         lines(numlines).point1 = point1 + 1;
         lines(numlines).point2 = point2 + 1;
         lines(numlines).length = linelength;
         lines(numlines).theta = theta(cbin);
         lines(numlines).rho = rho(rbin);
      end
   end
end
```
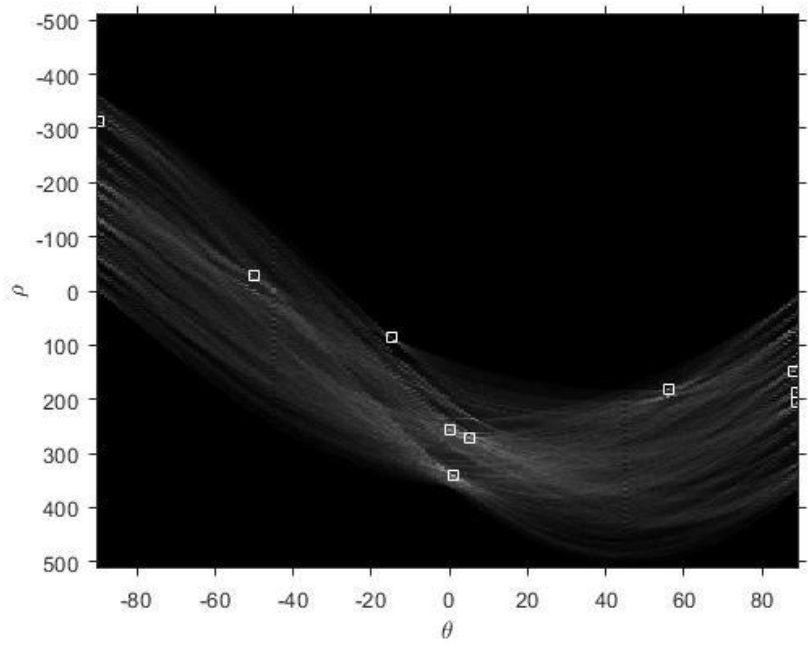

5. Main Code

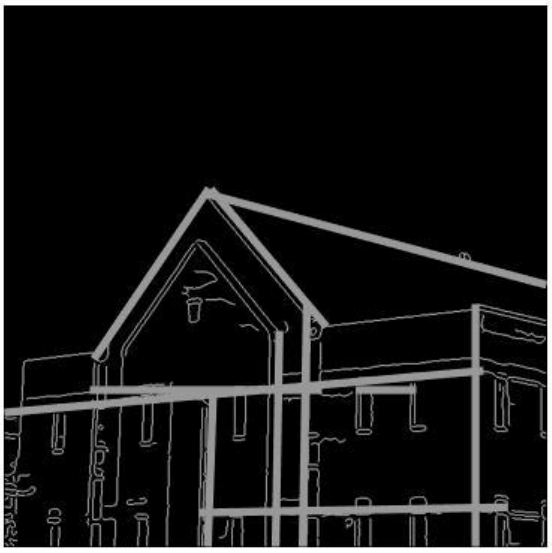
```
%%% Robot Vision%%%
%%% Dept. of Electronic Engineering
%%% 201314651 Lee Wonjai

% read the targeted image
IM_Edge = imread('C:\Users\user\OneDrive\¹ÙÅÁ È-¸é\2019 Æ¯°°, 4ÇÐ³â\4ÇÐ³â
2ÇÐ±â\·Î°¿°ñÀü\Homeworks\hw7\Edge.png');
[H,theta,rho] = hough(IM_Edge);
figure, imshow(H, [], 'XData',theta,
'YData',rho,'InitialMagnification','fit')
axis on, axis normal
xlabel('\theta'), ylabel('\rho')

[r, c] = houghpeaks(H, 10);
hold on
plot(theta(c), rho(r), 'linestyle', 'none', 'marker', 's', 'color', 'w')

lines = houghlines(IM_Edge, theta, rho, r, c);
figure, imshow(IM_Edge), hold on
for k = 1:length(lines)
   xy = [lines(k).point1; lines(k).point2];
   plot(xy(:,2), xy(:,1), 'lineWidth', 4, 'Color', [.6 .6 .6]);
end

r1 = [];
c1 = [];

for i = 1:length(c)
   if theta(c(i)) <= 10 && theta(c(i)) >= -10
      r1(end+1) = r(i);
      c1(end+1) = c(i);
   end
end

figure, imshow(H, [], 'XData',theta,
'YData',rho,'InitialMagnification','fit')
axis on, axis normal
xlabel('\theta'), ylabel('\rho')

hold on
plot(theta(c1), rho(r1), 'linestyle', 'none', 'marker', 's', 'color', 'w')

lines1 = houghlines(IM_Edge, theta, rho, r1, c1);
figure, imshow(IM_Edge), hold on
for j = 1:length(lines1)
   xy1 = [lines1(j).point1; lines1(j).point2];
   plot(xy1(:,2), xy1(:,1), 'lineWidth', 4, 'Color', [.6 .6 .6]);
end
```

02 Result 1

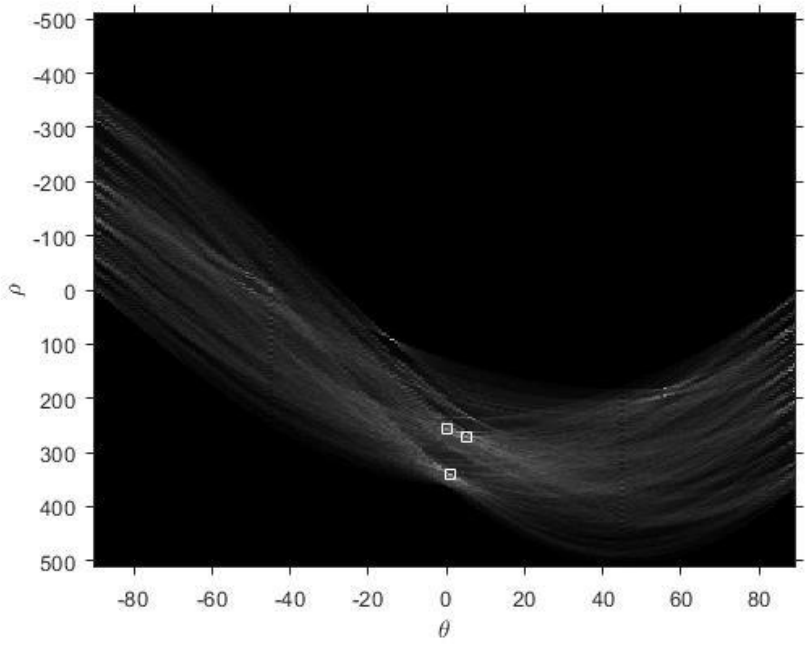
1. Hough Transformed Function and 10 Peaks



2. 10 peaks and Image



3. Hough Transformed Function within +- 10 Degree peaks



4. Within +- 10 Degree Peaks Image