A3_testing

October 17, 2018

1 A3: Frequency Domain Filtering

CS6640: Image Processing
Author: Cade Parkison

Jupyter Notebook Settings:
Make the output cells to use compact formatting:

```
In [109]: format compact
```

Plot images in the notebook, as opposed to `%plot native` which uses matlab gui window to plot

```
In [110]: %plot inline
```

```
In [16]: %plot native
```

TODO:

- Zero Padding
- refactor rings and angular to loop through each pixel first, calcultaing angle or distance, and then looping through segments

---

Test Image:

```
In [111]: im_rgb = imread('im2.jpg');
          im = rgb2gray(im_rgb);
          figure(1);imshow(im); title('Original - gray');
          figure(2);imshow(im_rgb); title('Original');
```

Original

Original - gray

1.1 Problem 1

Develop a texture feature analysis tool based on the 2D FFT power spectrum. For every 5x5 region in the image, compute the 2D FFT, compute the power spectrum, and use that as a 25-element feature vector. Produce a texture feature array, M*N by 25, and then use kmeans as in A2 to explore the usefulness of this for semantic region analysis (based on texture) in our videos.

Functions

```
In [ ]: %%file CS6640_FFT_texture.m

        function  T = CS6640_FFT_texture(im)
        % CS6640_FFT_texture - compute FFT texture parameters
        % On input:
        %     im (MxN array): input image
        % On output:
        %     T (M*Nx25 array): texture parameters
        %       each texture parameter is a column vector in T
        % Call:
```

```
%      T = CS6640_FFT_texture(im);
% Author:
%      Cade Parkison
%      UU
%      Fall 2018
%

[M,N] = size(im);
T = zeros(M,N, 25);
window = 5;

for i=3:M-2
    for j=3:N-2
        % get 5x5 window surrounding (i,j)
        w = im(i-2:i+2, j-2:j+2);
        % take FFT of window
        F = fft2(w);
        % get power spectrum of F
        ps = F.*conj(F);
        % Fill in T at (x,y,t) where t is the texture parameter 1:25
        T(i,j,1:25) = ps(:);
    end
end

% reshape T to (480*640 x 25)
T = reshape(T, M*N, 25);
```

Testing

In [30]:
```
%plot native
```

In [ ]:
```
clear all;close all;clc
```

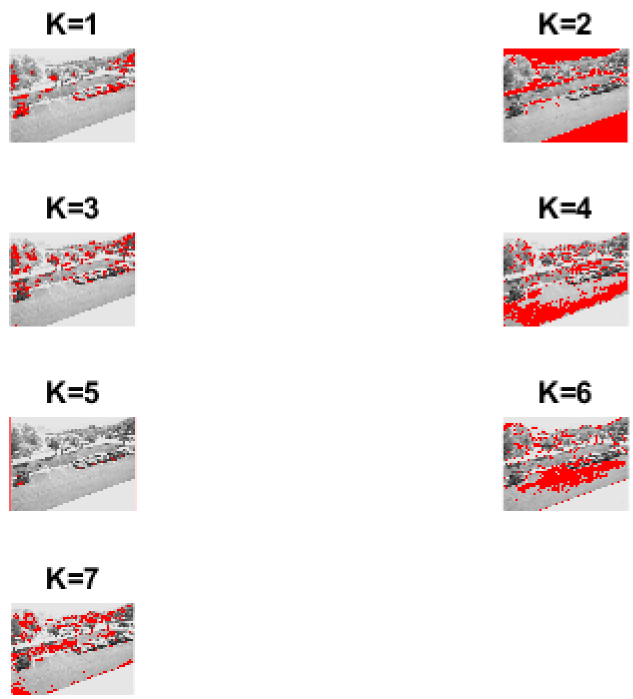
Calculate Texture parameters and pass them to k-means:

In [112]:
```
T = CS6640_FFT_texture(im);
[cidx,ctrs] = kmeans(T,7);
```

Plot the combo images for each k-means parameter:

In [113]:
```
subplot(4,2,1);combo(mat2gray(im),(reshape(cidx==1,480,640)));title('K=1');
subplot(4,2,2);combo(mat2gray(im),(reshape(cidx==2,480,640)));title('K=2');
subplot(4,2,3);combo(mat2gray(im),(reshape(cidx==3,480,640)));title('K=3');
subplot(4,2,4);combo(mat2gray(im),(reshape(cidx==4,480,640)));title('K=4');
```

```
subplot(4,2,5);combo(mat2gray(im),(reshape(cidx==5,480,640)));title('K=5');
subplot(4,2,6);combo(mat2gray(im),(reshape(cidx==6,480,640)));title('K=6');
subplot(4,2,7);combo(mat2gray(im),(reshape(cidx==7,480,640)));title('K=7');
%figure(8);combo(mat2gray(im),(reshape(cidx==8,480,640)));title('K=8');
%figure(9);combo(mat2gray(im),(reshape(cidx==9,480,640)));title('K=9');
```



1.2 Problem 2

Develop another FFT texture analysis approach based on radial segments of the power spectrum. A radial feature is defined by a radius pair:

$$f_{r_1,r_2} = \sum\sum |F(u,v)|^2$$

where $ {r_1}ˆ2 uˆ2 + vˆ2 < {r_2}ˆ2 $. Suppose there are 10 such pairs, specified by 10 radii; i.e.: $ R = {0, r_1, r_2, . . . , r_10} $ Produce a texture feature array, M*N by 10, and then use kmeans as in A2 to explore the usefulness of this for semantic region analysis (based on texture) in our videos.

Functions

In [ ]: %%file CS6640_rings.m

```
function rings = CS6640_rings
%  CS6640_rings - computes cell array of linear indices of each ring to be used with th
%
% On output:
%     rings (cell array) - Structure holding the (x,y) index pairs of each ring
% Call:
%     rings = CS6640_rings;
% Author:
%     Cade Parkison
%     UU
%     Fall 2018
%

rings = {};
% center
xc = 10; yc = 10;

for r=0:9;
    ring = [];
    rmin = r;
    rmax = r+1;
    for i=1:19
        for j=1:19
            % L-p norm from pixel to center of window
            p = 10;
            x = (xc-i)^p + (yc-j)^p;
            d = nthroot(x, p);
            if d >= rmin
                if d < rmax
                    % find linear index for corresponding (i,j) in the 19x19 matrix
                    ind = sub2ind([19,19], i, j);
                    ring = [ind; ring];
                end
            end
        end
    end
    rings{r+1} = ring;
end
end
```

In [ ]: %%file CS6640_FFT_radial.m

```
function  T = CS6640_FFT_radial(im)
%  CS6640_FFT_radial - compute FFT radial texture parameters
% On input:
```

```
%     im (MxN array): input image
% On output:
%     T (M*Nx10 array): texture parameters
%       each texture parameter is a column vector in T
% Call:
%     T = CS6640_FFT_radial(im);
% Author:
%     Cade Parkison
%     UU
%     Fall 2018
%

[M,N] = size(im);
T = zeros(M,N, 10);

% Cell array of length 10, each element containing list of linear indices for each ann
rings = CS6640_rings;

for i=10:M-9
    for j=10:N-9

        % get 19x19 window surrounding (i,j)
        w = im(i-9:i+9, j-9:j+9);
        % take FFT of window
        F = fft2(w);
        % get power spectrum of F
        ps = F.*conj(F);
        % Compute Radial segments of ps for each annulus
        ps_radial = zeros(1,10);
        for r=1:10
            ps_r = ps(rings{r});
            % sum square of ps_r
            ps_radial(r) = sum(ps_r.^2);
        end

        % Fill in T at (x,y,t) where t is the texture parameter 1:10
        T(i,j,1:10) = ps_radial(:);
    end
end

% reshape T to (480*640 x 10)
T = reshape(T, M*N, 10);
```

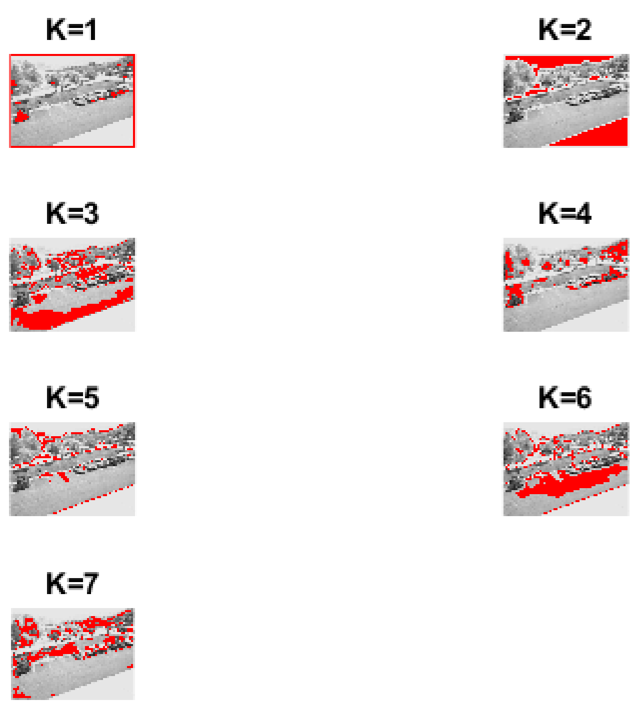
Testing

```
In [ ]: clear all;close all;clc;
```

Calculate Texture parameters and pass them to k-means:

```
In [114]: T_radial = CS6640_FFT_radial(im);
          [cidx_r,ctrs_r] = kmeans(T_radial,7);
```

```
In [115]: subplot(4,2,1);combo(mat2gray(im),(reshape(cidx_r==1,480,640)));title('K=1');
          subplot(4,2,2);combo(mat2gray(im),(reshape(cidx_r==2,480,640)));title('K=2');
          subplot(4,2,3);combo(mat2gray(im),(reshape(cidx_r==3,480,640)));title('K=3');
          subplot(4,2,4);combo(mat2gray(im),(reshape(cidx_r==4,480,640)));title('K=4');
          subplot(4,2,5);combo(mat2gray(im),(reshape(cidx_r==5,480,640)));title('K=5');
          subplot(4,2,6);combo(mat2gray(im),(reshape(cidx_r==6,480,640)));title('K=6');
          subplot(4,2,7);combo(mat2gray(im),(reshape(cidx_r==7,480,640)));title('K=7');
```



1.3 Problem 3

Develop another FFT texture analysis approach based on angular segments of the power spectrum. An angular feature is defined by a angle pair:

$$f_{1,2} = \sum \sum |F(u,v)|^2$$

where $_1 tan^1(v,u) \; < \; _2$, and $u^2 + v^2 \; < \; L^2$ for some appropriate L. Suppose there are 8 such segments, specified by 9 angles; i.e.: $A = \{0,,2,...,8\}$, where $=$ 45 degrees. Produce a texture feature array, M*N by 8 (where these cover between the following angles: $\{0, 45, 90, 135, 180, 225, 270, 315, 360\}$, and then use kmeans as in A2 to explore the usefulness of this for semantic region analysis (based on texture) in our videos.

Functions

In [4]:
```
%%file CS6640_angular.m

function segments = CS6640_angular(w)
%  CS6640_rings - computes cell array of linear indices of each angular segment to be
%
% On Input:
%    w (integer) - window size in pixels, must be odd
% On output:
%     segments (cell array) - Structure holding the (x,y) index pairs of each angular
% Call:
%     segments = CS6640_angular;
% Author:
%     Cade Parkison
%     UU
%     Fall 2018
%

segments = {};

% center of (w x w) window - (xc,yc)
xc = idivide(w, int32(2), 'ceil');
yc = xc;

for a=0:7;
    seg = [];
    % calculate min and max angles (degrees) for each angular segment
    amin = a*45 - 180;
    amax = (a+1)*45 -180;
    for i=1:w
        for j=1:w
            % Calculate angle from center of window to each window pixel
            dx = double(i - xc);
            dy = double(j - yc);
            theta = atan2d(dy,dx);
```

```
                if theta >= amin
                    if theta < amax
                        % find linear index for corresponding (i,j) in the wxw window matr
                        ind = sub2ind([w,w], i, j);
                        seg = [ind; seg];
                    end
                end
            end
        end
        segments{a+1} = seg;
    end
    end
```

Created file 'C:\Users\cadep\School\CS_6640\A3\CS6640_angular.m'.

In [48]:
```
%%file CS6640_FFT_angular.m

function  T = CS6640_FFT_angular(im)
%  CS6640_FFT_angular - compute FFT angular texture parameters
% On input:
%     im (MxN array): input image
% On output:
%     T (M*Nx8 array): texture parameters
%       each texture parameter is a column vector in T
% Call:
%     T = CS6640_FFT_angular(im);
% Author:
%     Cade Parkison
%     UU
%     Fall 2018
%

[M,N] = size(im);
T = zeros(M,N, 8);

% Window size W (must be odd number)
W = 11;
% half window
h = double(idivide(W, int32(2), 'floor'));

% Cell array of length 8, each element containing list of (x,y) indices for each angu
segments = CS6640_angular(W);

for i=h+1:M-h
    for j=h+1:N-h

        % get w x w window surrounding (i,j)
```

```
            window = im(i-h:i+h, j-h:j+h);
            % take FFT of window
            F = fft2(window);
            % get power spectrum of F
            ps = F.*conj(F);
            % Compute angular segments of ps
            ps_angular = zeros(1,8);
            for s=1:8
                ps_a = ps(segments{s});
                % sum square of ps_a
                ps_angular(s) = sum(ps_a.^2);
            end

            % Fill in T at (x,y,t) where t is the texture parameter 1:10
            T(i,j,1:8) = ps_angular(:);
        end
    end

    % reshape T to (480*640 x 8)
    T = reshape(T, M*N, 8);
```

```
Created file 'C:\Users\cadep\School\CS_6640\A3\CS6640_FFT_angular.m'.
```

Testing

In [49]:
```
clear all;close all;clc;
```

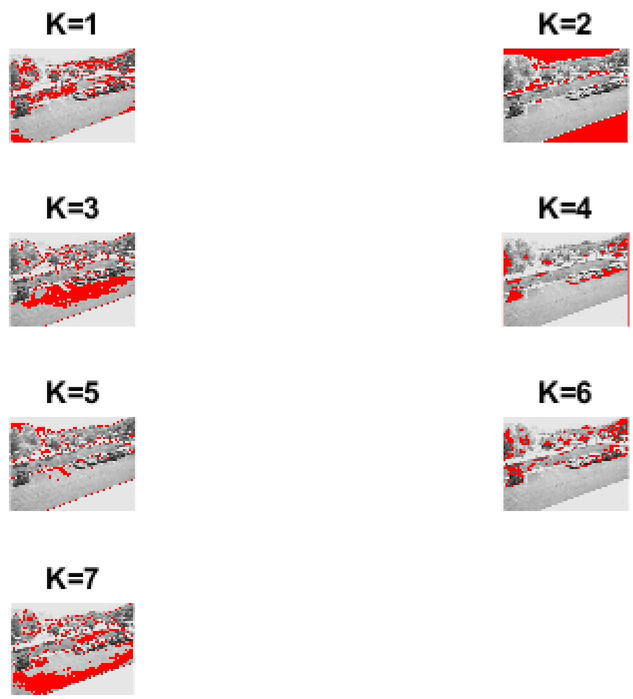
In [50]:
```
im_rgb = imread('im2.jpg');
im = rgb2gray(im_rgb);
```

Calculate Texture parameters and pass them to k-means:

In [116]:
```
T_angular= CS6640_FFT_angular(im);
[cidx_a,ctrs_a] = kmeans(T_angular,7);
```

In [117]:
```
subplot(4,2,1);combo(mat2gray(im),(reshape(cidx_a==1,480,640)));title('K=1');
subplot(4,2,2);combo(mat2gray(im),(reshape(cidx_a==2,480,640)));title('K=2');
```

```
subplot(4,2,3);combo(mat2gray(im),(reshape(cidx_a==3,480,640)));title('K=3');
subplot(4,2,4);combo(mat2gray(im),(reshape(cidx_a==4,480,640)));title('K=4');
subplot(4,2,5);combo(mat2gray(im),(reshape(cidx_a==5,480,640)));title('K=5');
subplot(4,2,6);combo(mat2gray(im),(reshape(cidx_a==6,480,640)));title('K=6');
subplot(4,2,7);combo(mat2gray(im),(reshape(cidx_a==7,480,640)));title('K=7');
```



1.4 Problem 4

Develop a Fourier shape descriptor function as described in the Zahn and Roskies paper (in 'lectures' link from class web page, weeks5-6). I.e., given a shape as a set of connected boundary points:

$$P = \{(x_i, y_i)\}$$

where i = 1 : N, of a shape (going clockwise), then the angle at each point is computed as:

$$(t) = atan2(y(t+w)y(t), x(t+w)x(t))$$

where w is a distance along the curve. is better produced by taking the previous direction, and adding to it the amount of change in angle to get the current angle. Then produce the function:

$$(t) = ((t)(0))mod2$$

and

$$(a) = ((\frac{La}{2}) + a)mod$$

where is computed over the interval [0, 2]. Take the FFT of , and if there are 2p Fourier coefficients, use the power of coefficients 2 to p as the shape descriptor (a vector).

Functions

In [30]:
```
%%file CS6640_gen_H.m

function H = CS6640_gen_H
% CS6640_gen_H - generate points on the boundary of letter H
% On input:
%      N/A
% On output:
%      H (43x2 array): x,y locations of boundary
% Call:
%      H = CS6640_gen_H;
% Author:
%      T. Henderson
%      UU
%      Fall 2018
%

H = [2,10; 3,10; 4,10; 4,9; 4,8; 4,7; 5,7; 6,7; 7,7; 7,8; 7,9; 7,10;...
    8,10; 9,10; 9,9; 9,8; 9,7;, 9,6; 9,5; 9,4; 9,3; 9,2; 8,2; 7,2; ...
    7,3; 7,4; 7,5; 6,5; 5,5; 4,5; 4,4; 4,3; 4,2; 3,2; 2,2; 2,3; 2,4;...
    2,5; 2,6; 2,7; 2,8;2,10];
```

```
Created file 'C:\Users\cadep\School\CS_6640\A3\CS6640_gen_H.m'.
```

In [49]:
```
%%file CS6640_gen_O

function C = CS6640_gen_O
% CS6640_gen_H - generate points on the boundary of letter H
% On input:
%      N/A
% On output:
%      H (43x2 array): x,y locations of boundary
% Call:
%      H = CS6640_gen_H;
% Author:
```

```
%     T. Henderson
%     UU
%     Fall 2018
%

C = [6,17; 7, 17; 8,17; 9,17; 10,17; 11,17; 12,17; 13,16; 14,15;...
    15,14; 16,13; 17,12; 17,11; 17,10; 17,9; 17,8; 17,7; 16,6; ...
    15,5; 14,4; 13,3; 13,2; 12,2; 11,2; 10,2; 9,2; 8,2; 7,2; 6,3;...
    5,4; 4,5; 3,6; 2,6; 2,7; 2,8; 2,9; 2,10; 2,11; 2,12; 3,13; ...
    4,14; 5,15; 6,16; 7,17];
```

```
Created file 'C:\Users\cadep\School\CS_6640\A3\CS6640_gen_O'.
```

In [46]:
```
%%file CS6640_FFT_shape.m

function  X = CS6640_FFT_shape(Z,w)
%  CS6640_FFT_shape - compute Fourier shape descriptors for a curve
% On input:
%     Z (Nx2 array): input curve (should be closed)
%     w (int): distance along curve to determine angles
% On output:
%     X ((N/2-1)x1 vector): the Fourier coefficients for the curve
% Call:
%     X = CS6640_FFT_shape(curve,2);
% Author:
%     Cade Parkison
%     UU
%     Fall 2018
%

s = size(Z);
N = s(1);
theta = zeros(1,N);

for i=1:N-1
    p1 = Z(i,:);
    p2 = Z(i+1,:);
    t = atan2((p2(2)-p1(2)),(p2(1)-p1(1)));
    theta(i) = t;
end

phi = zeros(1,N);
for i=1:N
    phi_rad = theta(i) - theta(1);
    % wrap to interval [0, 2*pi]
    phi(i) = phi_rad - 2*pi*floor(phi_rad/(2*pi));
end
```

```
        psi = zeros(1,N);

        F = fft(phi);

        % getting rid of the DC component as well as the symmetric values
        X = F(2:N/2);
```

```
Created file 'C:\Users\cadep\School\CS_6640\A3\CS6640_FFT_shape.m'.
```

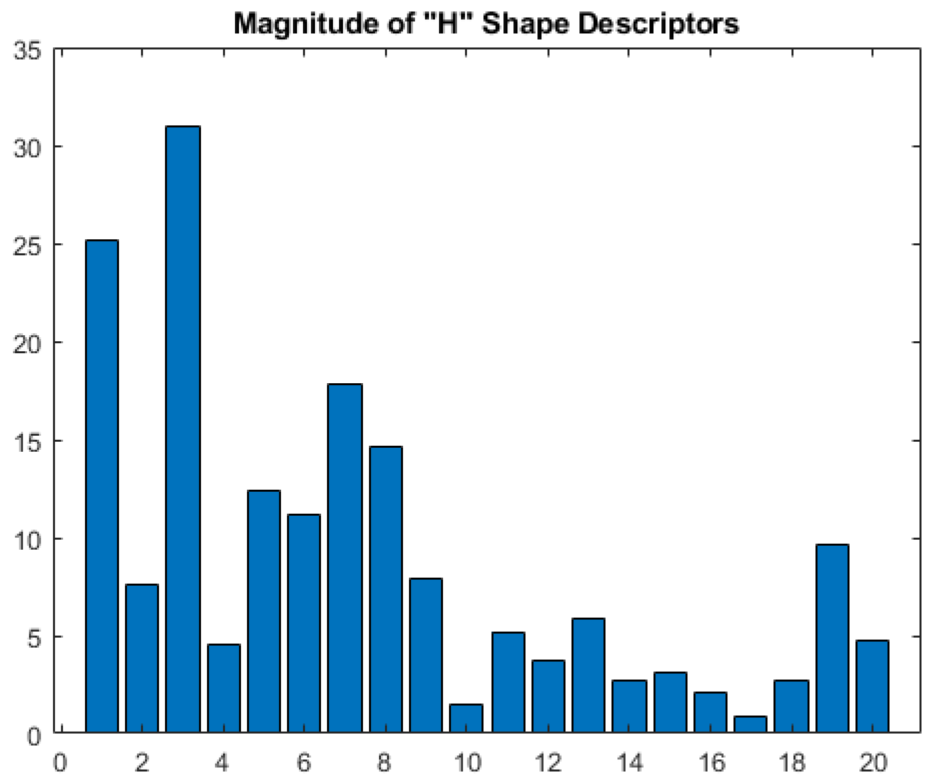
Testing

```
In [47]: clear all;close all;clc;
```

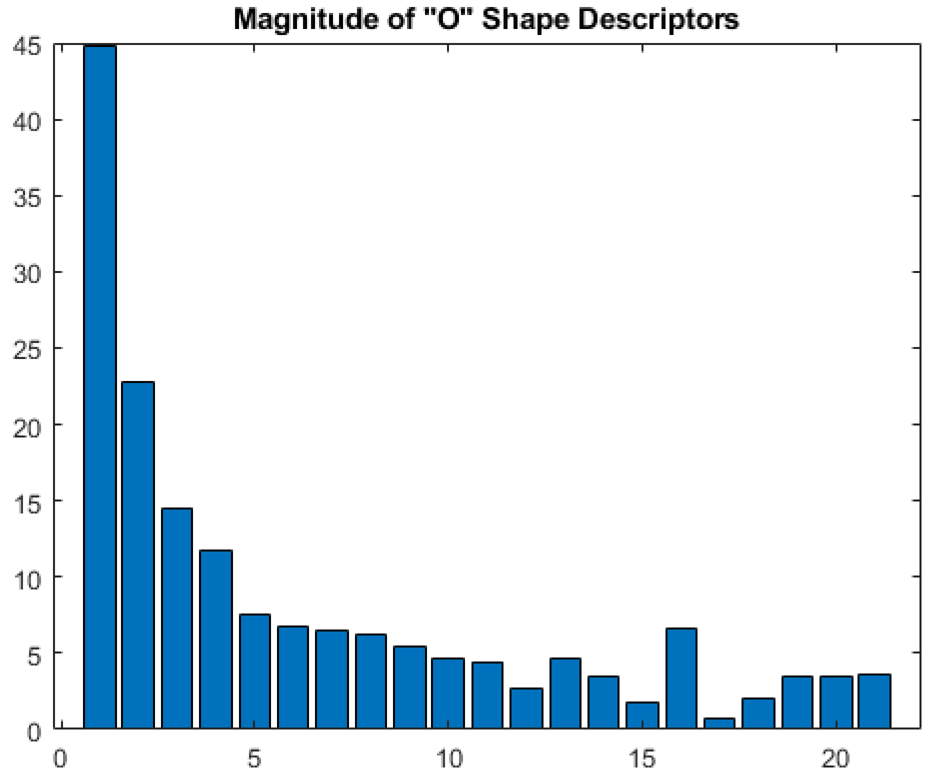
```
In [118]: H = CS6640_gen_H;
          O = CS6640_gen_O;
          size(O), size(H)
```

```
ans =
    44     2
ans =
    42     2
```

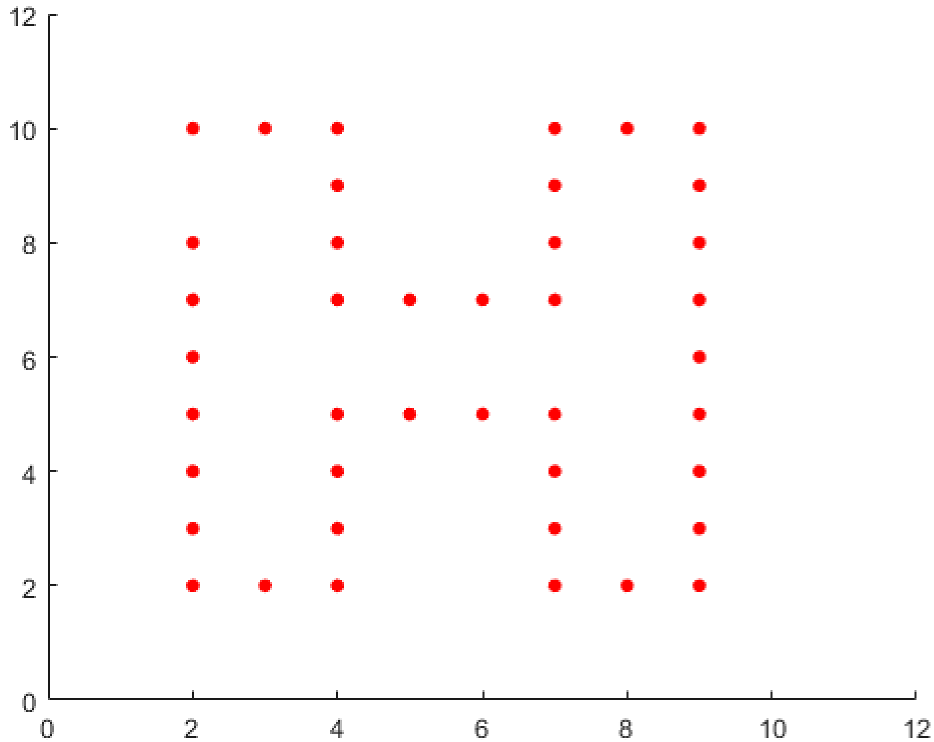
```
In [119]: X1 = CS6640_FFT_shape(H,2);

          bar(abs(X1))
          title('Magnitude of "H" Shape Descriptors')
```



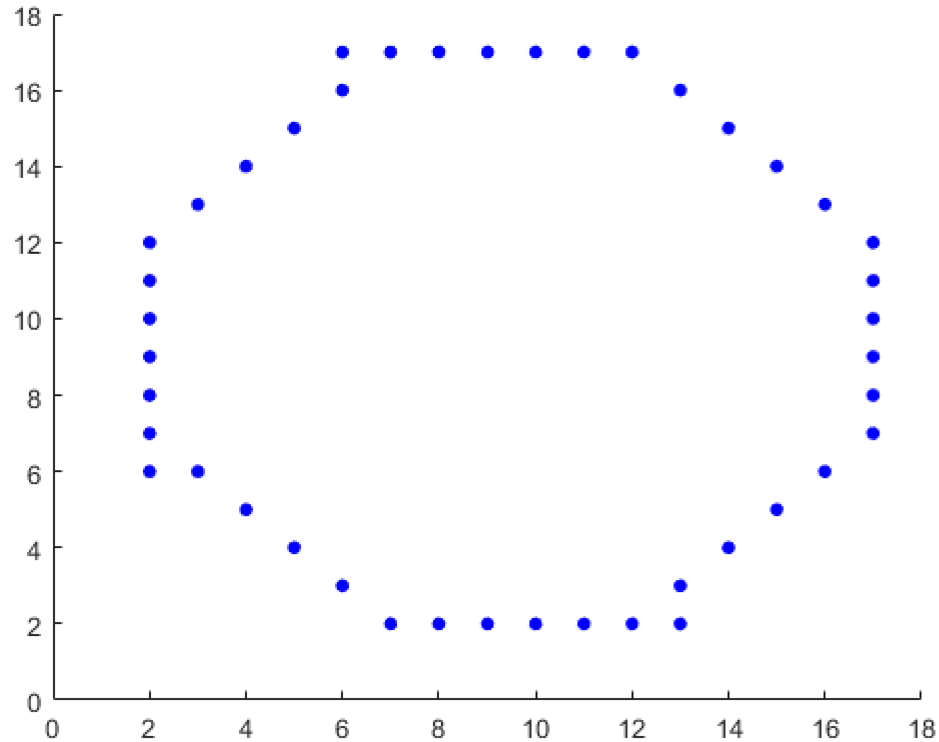

```
In [120]: X2 = CS6640_FFT_shape(0,2);

          bar(abs(X2))
          title('Magnitude of "O" Shape Descriptors')
```




```
In [121]: scatter(H(:,1), H(:,2), 25, 'red', 'filled')
          xlim([0 12]);
          ylim([0 12]);
```



In [122]:
```
scatter(O(:,1), O(:,2), 25, 'blue', 'filled')
xlim([0 18]);
ylim([0 18]);
```


0
2
4
6
8
10
12
14
16
18
0
2
4
6
8
10
12
14
16
18