

Calibrating your phone's camera

Load a certain number of images captured using your phone; detect points pixel coordinates and assign the corresponding space ones in mm.

```
clear imageData
folder = 'iphone_images';
files = dir(strcat(folder, '/*.jpg'));
n = numel(files); % find number of files in folder
imageData(n,1) = struct();
squaresize = 17; % mm
chessSize = [10,11];
for i = 1:n
    imageFileName = fullfile(folder,files(i).name);
    img = imread(imageFileName);
    % if image is not already B/N
    if length(size(img)) > 2
        img = rgb2gray(img);
    end
    imageData(i).I = img;
    imageData(i).XYpixel = detectCheckerboardPoints(imageData(i).I, ...
        'PartialDetections', false);
    XYpixel = imageData(i).XYpixel;
    clear Xmm Ymm
    for j=1:length(XYpixel)
        % this function provides the row and column position of
        % each point on a checkerboard of the given size
        [row,col] = ind2sub(chessSize,j);
        % corresponding coordinates for each point in millimiters
        Xmm = (col-1)*squaresize;
        Ymm = (row-1)*squaresize;
        imageData(i).XYmm(j,:) = [Xmm, Ymm];
    end
end
```

Estimate camera parameters using the points detected and Zhang procedure

```
% call the already implemented function, which can be
% found in 'utils' folder
clear data
data = estimateCamParam(imageData, n);
```

Compute reprojection error

```
idx = 4; % choose an image
```

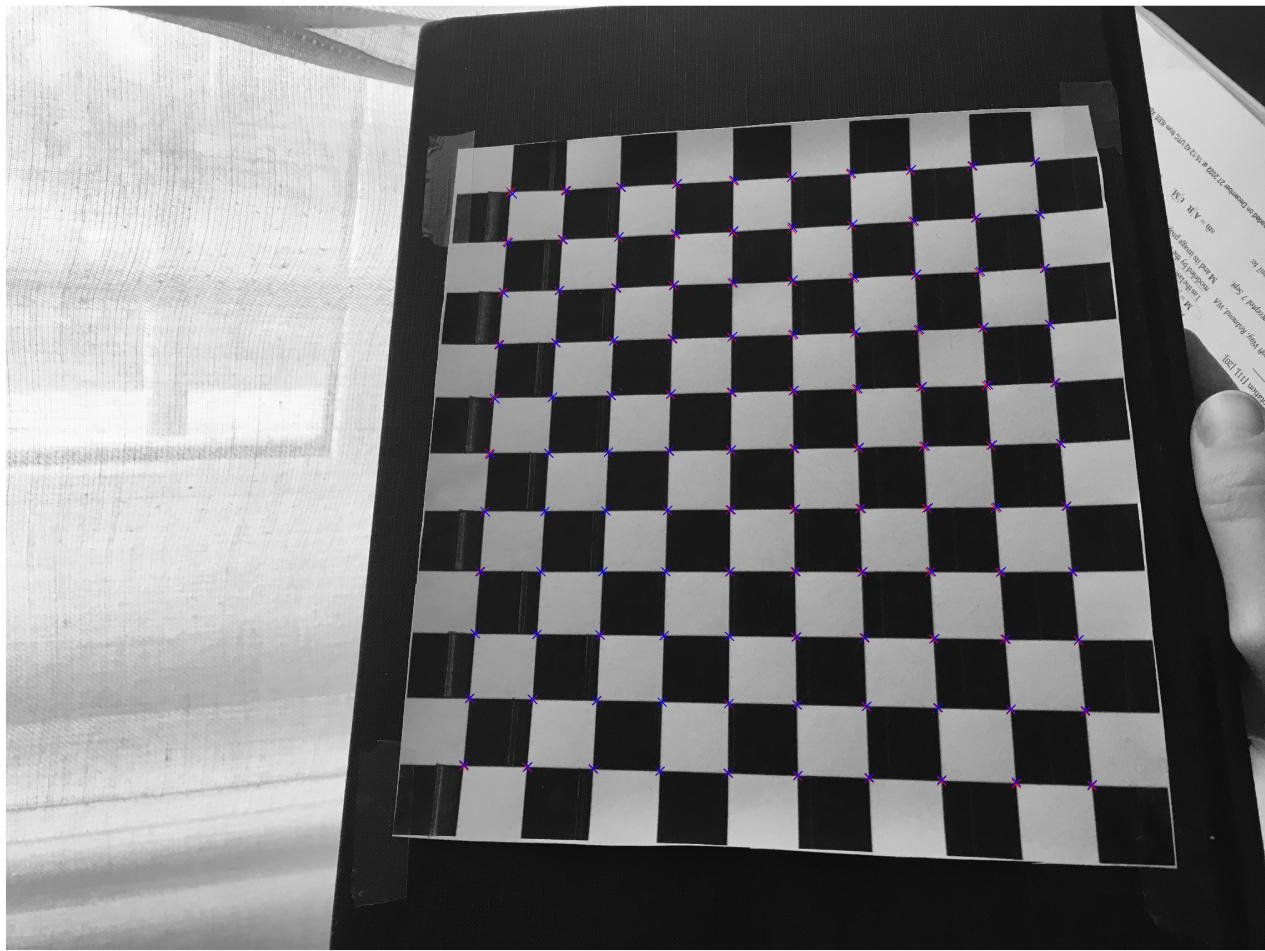
```

XYpixel = data(idx).XYpixel;
XYmm = data(idx).XYmm;
error = 0;

figure
imshow(data(idx).I, 'initialmagnification',200);
title(num2str(idx))
hold on

for i=1:length(XYpixel)
    % coordinates of point in mm
    Xmm=XYmm(i,1);
    Ymm=XYmm(i,2);
    % 3D point m
    m = [Xmm; Ymm; 0; 1];
    P = data(idx).P;
    estimated_u = (P(1,:)*m)/(P(3,:)*m);
    estimated_v = (P(2,:)*m)/(P(3,:)*m);
    % compute the error wrt visible points on the image
    Xpixel=XYpixel(i,1);
    Ypixel=XYpixel(i,2);
    eu = estimated_u - Xpixel; % error on u
    ev = estimated_v - Ypixel; % error on v
    error = error + eu^2 + ev^2;
    scatter(Xpixel,Ypixel, 'x', 'r');
    scatter(estimated_u,estimated_v, 'x', 'b');
end

```



```
fprintf("Sum of geomtric errors is: %d pixels^2", error)
```

```
Sum of geomtric errors is: 1.581407e+03 pixels^2
```

Compute the reprojection error for each image and save it in data structure.

```
for i=1:n
    error = 0;
    XYpixel = data(i).XYpixel;
    XYmm = data(i).XYmm;
    for j=1:length(XYpixel)
        % coordinates of point in mm
        Xmm=XYmm(j,1); % x
        Ymm=XYmm(j,2); % y
        m = [Xmm; Ymm; 0; 1];
        P = data(i).P;

        estimated_u = (P(1,:)*m)/(P(3,:)*m);
        estimated_v = (P(2,:)*m)/(P(3,:)*m);
```

```

% measure error wrt points detected on keyboard by
% detectCheckerboardPoints function
Xpixel=XYpixel(j,1);
Ypixel=XYpixel(j,2);
eu = estimated_u - Xpixel; % error on u
ev = estimated_v - Ypixel; % error on v
error = error + eu^2 + ev^2;
end
data(i).error = error;
fprintf("Error for image %d = %d pixel^2\n", i, error);
end

```

```

Error for image 1 = 8.082550e+02 pixel^2
Error for image 2 = 1.612926e+03 pixel^2
Error for image 3 = 1.912090e+03 pixel^2
Error for image 4 = 1.581407e+03 pixel^2
Error for image 5 = 1.069840e+04 pixel^2
Error for image 6 = 5.334811e+03 pixel^2
Error for image 7 = 5.680682e+03 pixel^2
Error for image 8 = 2.313815e+03 pixel^2
Error for image 9 = 1.178627e+04 pixel^2
Error for image 10 = 2.761833e+03 pixel^2
Error for image 11 = 1.603403e+03 pixel^2
Error for image 12 = 1.397509e+03 pixel^2
Error for image 13 = 2.421081e+03 pixel^2
Error for image 14 = 1.397719e+03 pixel^2
Error for image 15 = 1.638781e+04 pixel^2
Error for image 16 = 1.974134e+03 pixel^2
Error for image 17 = 3.339215e+03 pixel^2
Error for image 18 = 1.409757e+04 pixel^2
Error for image 19 = 2.193277e+04 pixel^2
Error for image 20 = 3.037565e+03 pixel^2

```

Superimpose a 3D object to the calibration plane

Superimpose a cylinder to the calibration plane, in all the images employed for the calibration and obtain corresponding 2D representation.

The cylinder has center $(x_0, y_0) = (60, 60)$, height $h = 50$ and radius $r = 40$.

```

figure
for idx=4:7
    subplot(2,2,idx-3);
    imshow(data(idx).I)
    hold on

    % measures
    d = 80; % diameter
    r = d/2;
    h = 50; % height
    % center
    x0=60;
    y0=60;

    % points to represent the circles

```

```

n_points = 40;
angle = pi/n_points;
clear m
% m will contain all the points of the two bases

m = zeros(n_points*2, 4);
for i = 1:n_points
    x = x0 + r.*cos(angle + (2*pi/n_points)*i);
    y = y0 + r.*sin(angle + (2*pi/n_points)*i);
    a = [x;y;0;1]; % point at the bottom of cylinder
    b = [x;y;h;1]; % corresponding point at top
    m(i,:) = a; % bottom basis
    m(i+n_points,:)= b; % top basis
end
% compute corresponding points in the image reference frame
projected = zeros(n_points*2, 3);
for i = 1:length(m)
    res = data(idx).P*m(i,:)';
    if res(3) > 0
        if i > n_points % only for points which have z != 0
            m(i, 3)= -h;
        end
        res = data(idx).P*m(i,:)';
        projected(i,:) = res./res(3);
    else
        projected(i,:) = res./res(3);
    end
end
x_bottom = projected(1:n_points,1);
y_bottom = projected(1:n_points,2);
x_top = projected(n_points+1:n_points*2,1);
y_top = projected(n_points+1:n_points*2,2);
% try to show the corpus of cylinder
% find rightmost and leftmost point
dist = zeros(n_points/2,1);
for s=1:n_points/2
    dist(s) = sqrt((x_bottom(s) - x_bottom(s+n_points/2)).^2 + ...
    (y_bottom(s) - y_bottom(s+n_points/2)).^2);
end

[~, i] = max(dist);
k = i + n_points/2;
if (y_bottom(i) > y_top(i) && x_bottom(i) < x_bottom(k) ) || ...
    (y_bottom(i) < y_top(i) && x_bottom(i) > x_bottom(k))
    border_x = [x_bottom(i), x_top(i:k)', x_bottom(k:end)', x_bottom(1:i-1)'];
    border_y = [y_bottom(i), y_top(i:k)', y_bottom(k:end)', y_bottom(1:i-1)'];
else
    border_x = [x_top(i), x_bottom(i:k)', x_top(k:end)', x_top(1:i-1)'];
    border_y = [y_top(i), y_bottom(i:k)', y_top(k:end)', y_top(1:i-1)'];
end

```

```
patch(border_x, border_y, 'green', 'LineStyle', 'none', ...
      'FaceColor', 'green', 'FaceAlpha', 0.8);
% show basis
patch(x_bottom, y_bottom, 'red', 'LineStyle', 'none', ...
      'FaceColor', 'red', 'FaceAlpha', 0.3);
patch(x_top, y_top, 'blue', 'LineStyle', 'none', ...
      'FaceColor', 'blue', 'FaceAlpha', 0.6);
end
```

