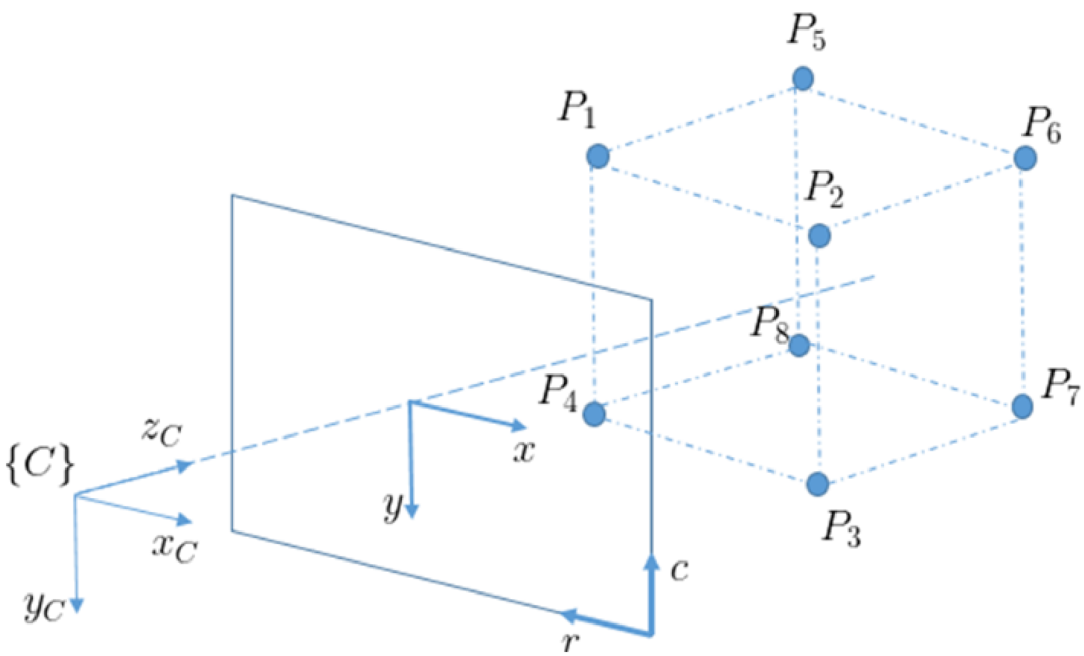
```
function projections = project_points(points, f, alpha_x, alpha_y, o_r, o_c,
p)
    % Project 3D points onto a 2D plane (CCD) using camera parameters.
    %
    % Args:
    % - points: A Nx3 matrix of 3D points in the form [X1, Y1, Z1; X2, Y2,
Z2; ...].
    % - f: Focal length in mm.
    % - alpha_x: Pixel scale in x direction (pixels per mm).
    % - alpha_y: Pixel scale in y direction (pixels per mm).
    % - o_r: Image center in the row (u) direction.
    % - o_c: Image center in the column (v) direction.
    % - p: Print the projected points with a label (true or false).
    %
    % Returns:
    % - projections: A Nx2 matrix of projected 2D points on the CCD in pixel
coordinates.

    % Initialize projections array
    projections = zeros(size(points, 1), 2);

    for i = 1:size(points, 1)
        X = points(i, 1);
        Y = points(i, 2);
        Z = points(i, 3);

        % Calculate the projection onto the CCD
        u = -f * (X / Z) * alpha_x + o_r;
        v = -f * (Y / Z) * alpha_y + o_c;

        % Store the projected point (u, v)
        projections(i, :) = [u, v];
    end

    % Round the projections to 2 decimal places
    projections = round(projections, 2);

    if p
        % Print each projected point with a label
        for i = 1:size(projections, 1)
            fprintf('P%d = [%0.2f, %0.2f]\n', i, projections(i, 1),
projections(i, 2));
        end
    end
end

function d = calculate_distance(f, alpha_x, alpha_y, o_r, o_c, real_dist,
p1, p2)
    % Calculate the distance using given camera parameters and points.
    %
```

```
    % Args:
    % - f: Focal length in mm.
    % - alpha_x: Pixel scale in x direction (pixels per mm).
    % - alpha_y: Pixel scale in y direction (pixels per mm).
    % - o_r: Image center in the row (u) direction.
    % - o_c: Image center in the column (v) direction.
    % - real_dist: Real distance between points in mm.
    % - p1: First point in pixel coordinates (1x2 vector).
    % - p2: Second point in pixel coordinates (1x2 vector).
    %
    % Returns:
    % - d: Calculated distance.

    % Convert pixel coordinates to real-world coordinates
    p1_real = [p1(1) / alpha_x, p1(2) / alpha_y];
    p2_real = [p2(1) / alpha_x, p2(2) / alpha_y];

    % Calculate the pixel distance between the two points
    pixel_dist = sqrt((p1_real(1) - p2_real(1))^2 + (p1_real(2) -
p2_real(2))^2);

    % Calculate the distance
    d = (f * real_dist) / pixel_dist;
end
```

Q4.1

A cubic object is placed in front of a camera with frame $\{C\}$, as in figure:



The camera parameters are:
$f = 8 \text{ mm}$
$\alpha_x = \frac{1}{s_x} = 79.2 \text{ pix/mm}$
$\alpha_y = \frac{1}{s_y} = 120.5 \text{ pix/mm}$
The frame of reference of the camera is placed in the positive x-y quadrant with respect to frame $\{C\}$, at the corner of the CCD, and the distance between the CCD frame and the focal axis is $o_r = 250 \text{ pix}$ and $o_c = 250 \text{ pix}$.

The corners of the cubic object are placed in the following positions w.r.t. the camera frame $\{C\}$:
$P_1 = [-0.1; -0.1;\ 1] \text{ m}$
$P_2 = [\ 0.2; -0.1;\ 1] \text{ m}$
$P_3 = [\ 0.2;\ 0.2;\ 1] \text{ m}$
$P_4 = [-0.1;\ 0.2;\ 1] \text{ m}$
$P_5 = [-0.1; -0.1;\ 2] \text{ m}$
$P_6 = [\ 0.2; -0.1;\ 2] \text{ m}$
$P_7 = [\ 0.2;\ 0.2;\ 2] \text{ m}$
$P_8 = [-0.1;\ 0.2;\ 2] \text{ m}$

Find the projection $\hat{P}_i$ in pixels on the CCD of all eight points. Choose the correct answer:

```
% Given camera parameters
f = 8;              % Focal length in mm
alpha_x = 79.2;    % Pixel scale in x direction (pixels per mm)
alpha_y = 120.5;   % Pixel scale in y direction (pixels per mm)
o_r = 250;          % Image center row (u) in pixels
o_c = 250;          % Image center column (v) in pixels

% 3D points in the camera coordinate frame
points = [
```

```
     -0.1, -0.1, 1;
      0.2, -0.1, 1;
      0.2,  0.2, 1;
     -0.1,  0.2, 1;
     -0.1, -0.1, 2;
      0.2, -0.1, 2;
      0.2,  0.2, 2;
     -0.1,  0.2, 2
];

% Call the function
projections = project_points(points, f, alpha_x, alpha_y, o_r, o_c, true);
```

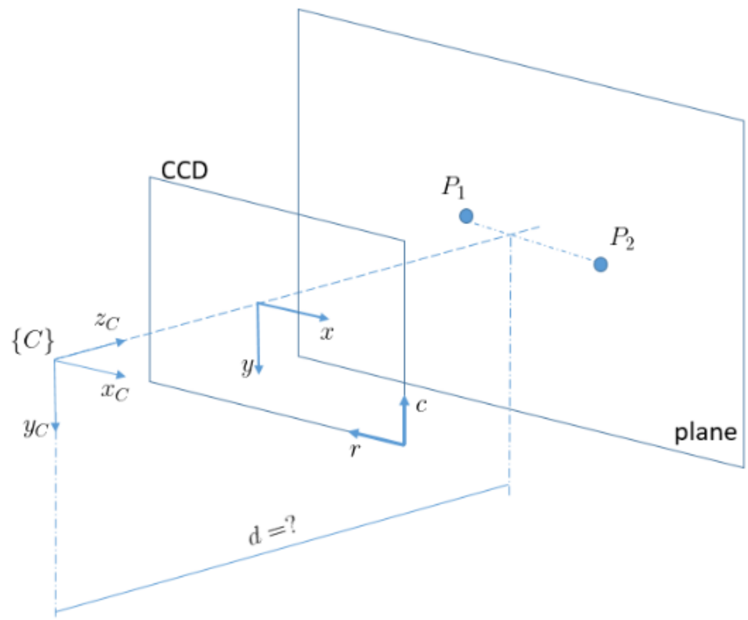
```
P1 = [313.36, 346.40]
P2 = [123.28, 346.40]
P3 = [123.28, 57.20]
P4 = [313.36, 57.20]
P5 = [281.68, 298.20]
P6 = [186.64, 298.20]
P7 = [186.64, 153.60]
P8 = [281.68, 153.60]
```

Q4.2

Two points, P_1 and P_2, are projected on the CCD at pixels
$r_1 = 313 \text{ pix}, c_1 = 250 \text{ pix}$
and
$r_2 = 155 \text{ pix}, c_2 = 250 \text{ pix},$
respectively.

Both points lie on a plane parallel to the CCD plane, and the distance d of the plane where the two points lie, and the camera frame {C} is unknown.

The distance between the two points is $\|P_1 - P_2\| = 0.3 \text{ m}$.



The camera parameters are:
$f = 8 \text{ mm}$
$\alpha_x = \frac{1}{s_x} = 79.2 \text{ pix/mm}$
$\alpha_y = \frac{1}{s_y} = 120.5 \text{ pix/mm}$
The frame of reference of the camera is placed in the positive x-y quadrant with respect to frame $\{C\}$, at the corner of the CCD, and the distance between the CCD frame and the focal axis is $o_r = 250 \text{ pix}$ and $o_c = 250 \text{ pix}$.

Find, within reasonable precision, the distance d from the camera origin to the plane of the two points (z coordinate of the points w.r.t. frame {C})

Vælg en svarmulighed

- $d = 0.78 \text{ m}$
- $d = 1.25 \text{ m}$
- $d = 1.8 \text{ m}$
- $d = 0.95 \text{ m}$
- $d = 1.2 \text{ m}$
- $d = 1 \text{ m}$
- $d = 3 \text{ m}$

```matlab
% Example usage
f = 8;                  % Focal length in mm
alpha_x = 79.2;         % Pixel scale in x direction (pixels per mm)
alpha_y = 120.5;        % Pixel scale in y direction (pixels per mm)
o_r = 250;              % Image center row (u) in pixels
o_c = 250;              % Image center column (v) in pixels
real_dist = 0.3;        % Real-world distance between the points in mm
p1 = [313, 250];        % First point in pixel coordinates
p2 = [155, 250];        % Second point in pixel coordinates

% Calculate the distance
d = calculate_distance(f, alpha_x, alpha_y, o_r, o_c, real_dist, p1, p2);

% Display the result
fprintf('Calculated distance: %.2f mm\n', d);
```

```
Calculated distance: 1.20 mm
```