Mobile robot short Project

Table of Contents

Given the kown workspace: Sensors_Data.mat, and Enviroment.png

Answer the following question:

Loading environment

```
clear
close all
clf
```

```
load("Encoder_Data.mat")
```

```
load("Sensors_Data.mat")
```

```
load("Laser_Data.mat")
```

Pose estimation given encoder data (10%)

Before start:

- Open the Simulink model EKF_Pose_estimation.slx and get familiar with: 'Where2Find_Code.pdf'.
- Have a look to section See an animation of the file: 3_MR_SP_support.mlx

Every thing is done, the exercise consist in compile in a mlx file all the concepts.

1.- Implement in this mlx file:

a) Pose_theoric, asumme no noise. (review **Mobile Robot Kinematics** folder)

b) Pose_estimation by adding noise in odometry. review **Pose uncertanty** folder)

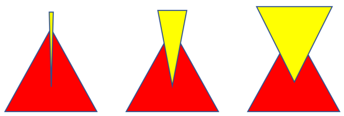
c) Ricatti equation for estimating the covariance matrix representing the uncertanty in the robot pose.

2.- Display in a figure:

a) x,y poses for both trajectories: theoric and estimated

b) ellipses representing x,y uncertanty. Do it every 15-20 poses.

c) represent uncertanty in orientation by adding a isosceles triange in front of the robot the base



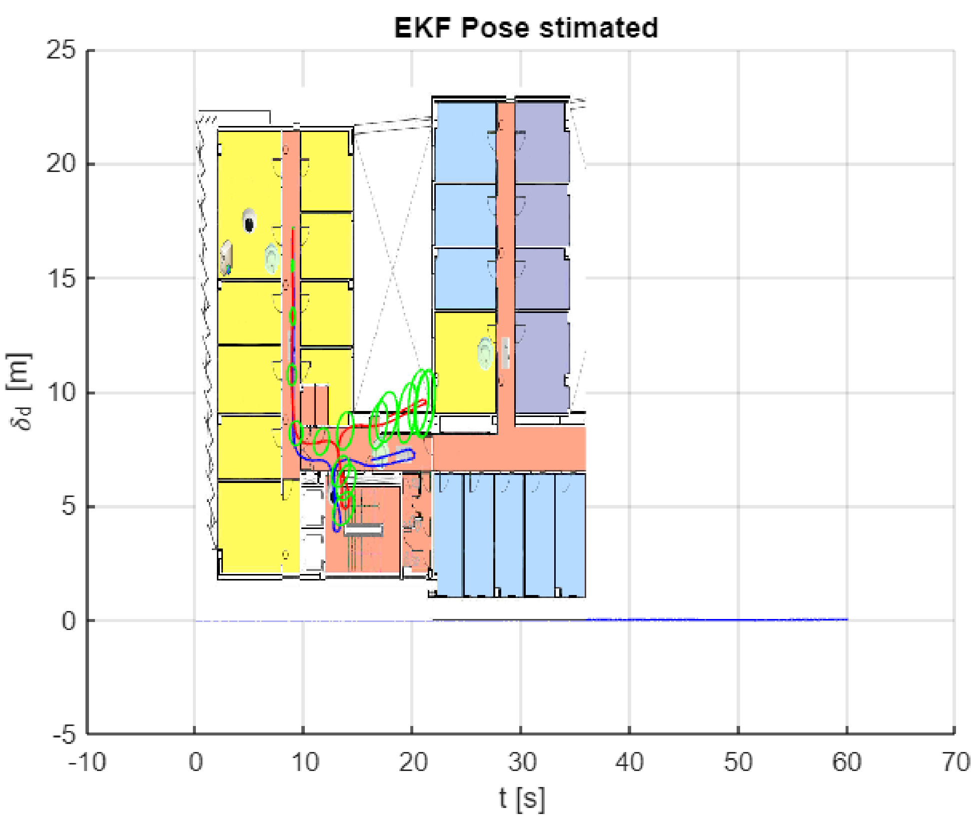
The robot will be represented by a triangle: Robot= [0 -0.2 0 1;0.4 0 0 1;0 0.2 0 1]

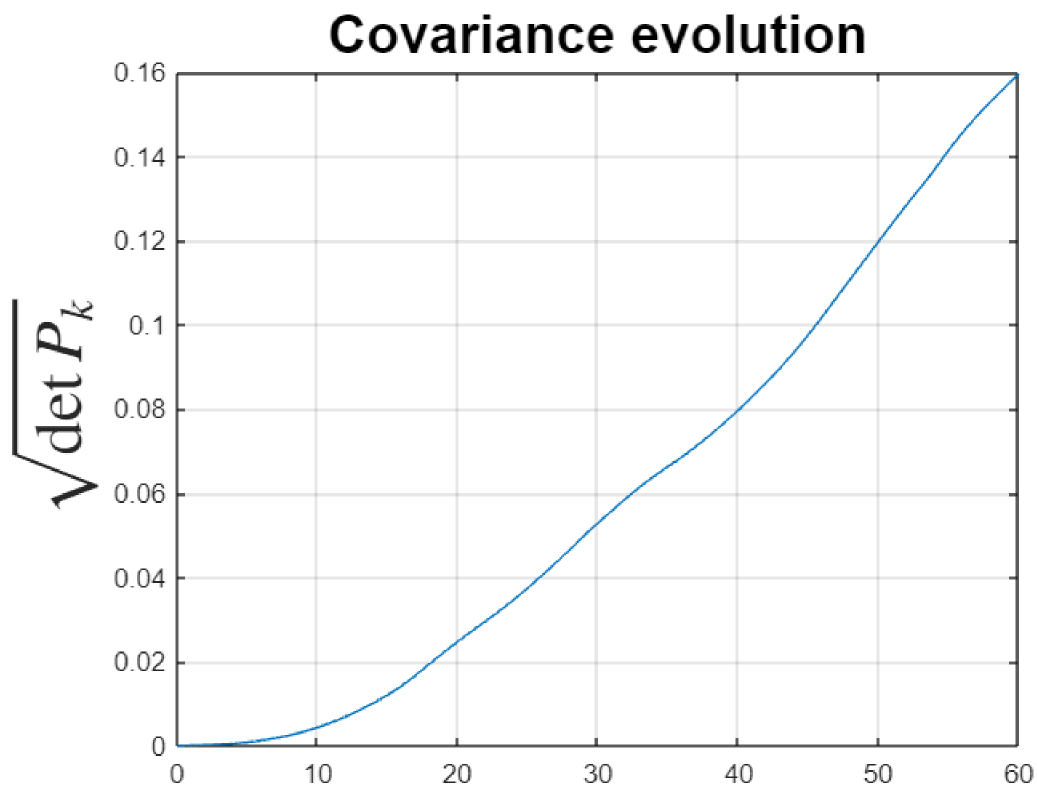
Record a movie of the robot moving along the corridor displaying both trajectories.

See: help VideoWriter to get familiar with the matlab functions

```
% Add your code here
sim("EKF_Pose_estimation_1.slx" )
```

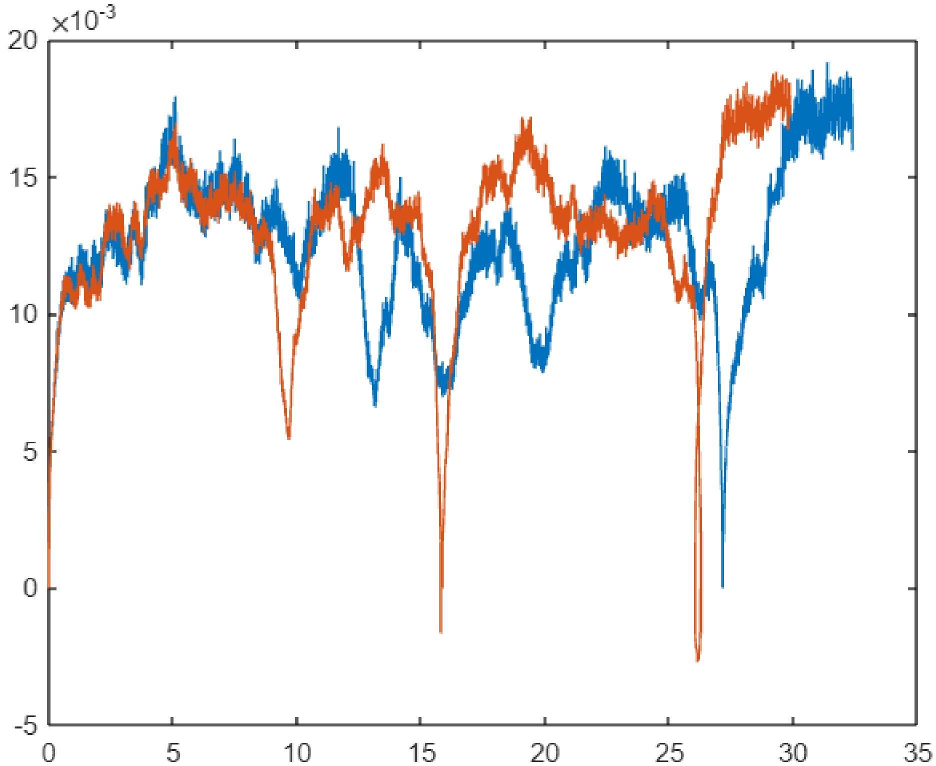
```
ProcNoiseTheta = 9.0000e-06
Ts = 0.0200
```





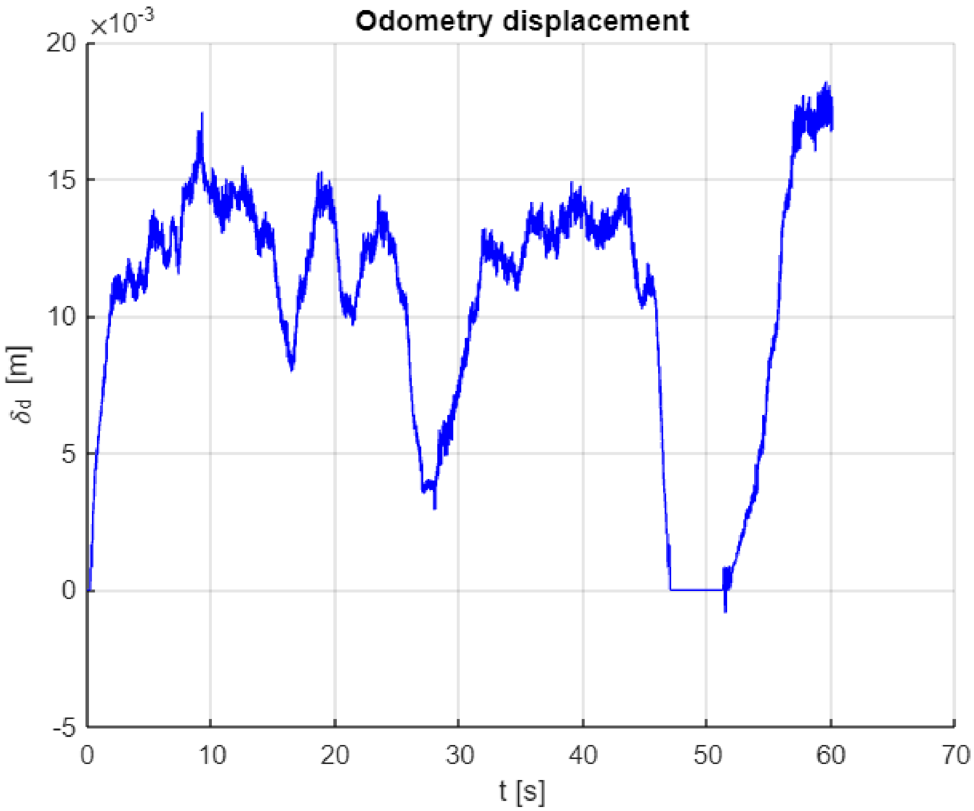
1.a) Pose_theoric, assuming no noise

```
r = 0.1;
time = Ts;
t = R_acu(:,1);
L_inc = diff(L_acu(:,2));
R_inc = diff(R_acu(:,2));

delta_d=(R_inc+L_inc)/2;
delta_t=(R_inc-L_inc)/(W);

plot(R_acu(2:3004,2),R_inc(:))
hold on
plot(L_acu(2:3004,2), L_inc(:))
```



Odometry displacement

```
figure
hold on
grid on
title('Odometry displacement');
xlabel ('t [s]');
ylabel ('\delta_d [m]')
plot(t(2:end),delta_d,'b');
```



Theoric trajectory calculation

```
Initial_pose=transl(8.95,17.2,0)*trotz(-pi/2);
Initial_position=transl(Initial_pose);
Initial_orientation=-pi/2;
x(1)=Initial_position(1);
y(1)=Initial_position(2);
o(1)=Initial_orientation;
for i=1:(length(t)-1)
    x(i+1) = x(i)+delta_d(i)*cos(o(i));
    y(i+1) = y(i)+delta_d(i)*sin(o(i));
    o(i+1) = mod(o(i)+delta_t(i),2*pi);
end
```

1.b) Pose_estimation by adding noise in odometry

```
noise_std = 0.002; % adjust as needed
ProcNoiseTheta;
```

```
ProcNoiseTheta = 9.0000e-06
```

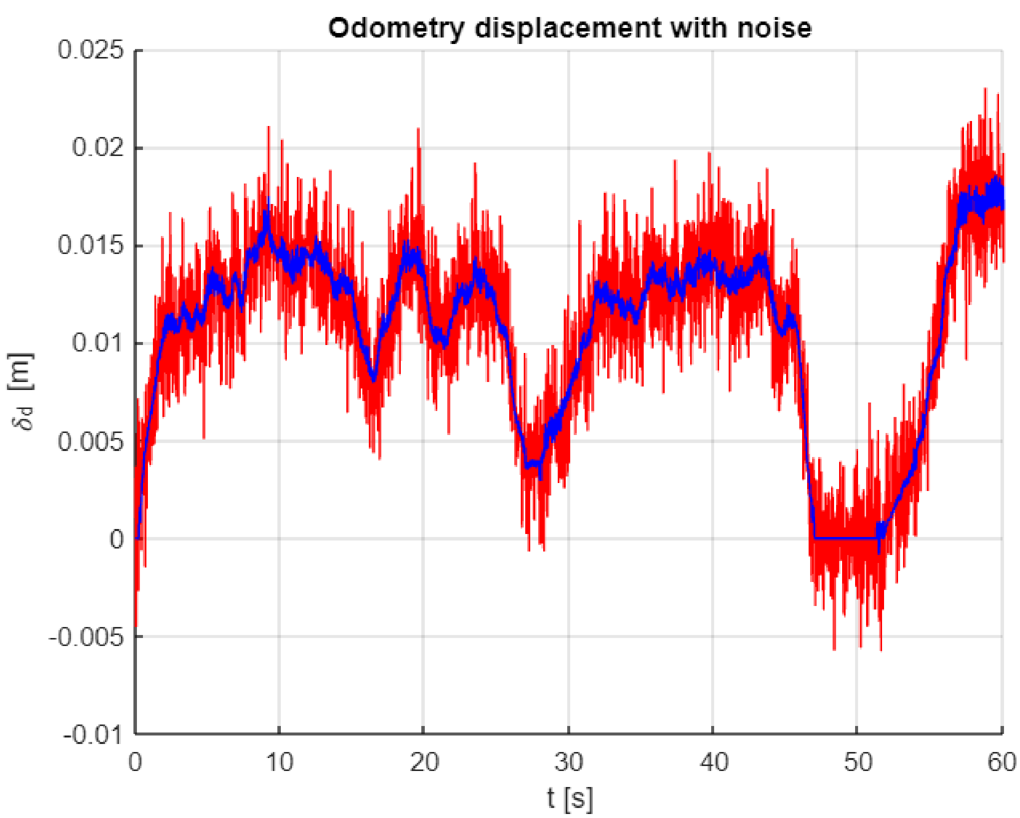
```
ProcNoiseD;
```

```
ProcNoiseD = 3.6100e-04
```

```
delta_d_n = delta_d + randn(length(t)-1,1)*noise_std;
delta_t_n = delta_t + randn(length(t)-1,1)*noise_std;
```

Odometry displacement with noise

```
figure
hold on

plot(t(2:end),delta_d_n,'r')
xlim ([0 Tf])
grid on
title('Odometry displacement with noise')
xlabel ('t [s]')
ylabel ('\delta_d [m]')
plot(t(2:end),delta_d,'b')
```



Estimated (noisy) trajectory calculation

```
x_n(1)=Initial_position(1);
y_n(1)=Initial_position(2);
o_n(1)=Initial_orientation;
for i=1:(length(t)-1)
    x_n(i+1) = x_n(i)+delta_d_n(i)*cos(o_n(i));
    y_n(i+1) = y_n(i)+delta_d_n(i)*sin(o_n(i));
    o_n(i+1) = mod(o_n(i)+delta_t_n(i),2*pi);
end
```

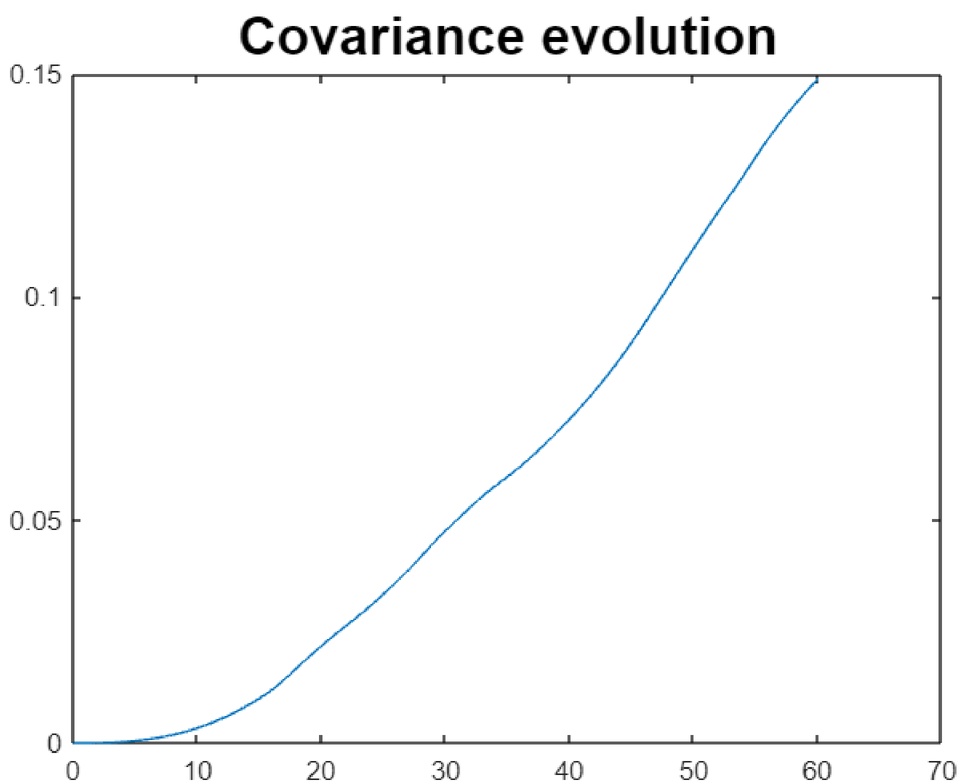
1.c) Ricatti equation

```
V = [ProcNoiseD 0; 0 ProcNoiseTheta];
F_x(:,:,i)= [1 0 -delta_d(1)*sin(o(1));....
    0 1  delta_d(1)*cos(o(1));....
    0 0 1];
F_v(:,:,i) = [cos(o(1)) 0;sin(o(1)) 0;0 1];
P(:,:,i) = F_x(:,:,1)*(eye(3)*0.0001)*F_x(:,:,1)' + F_v(:,:,1)*...
    [V(1) 0; 0 V(2,2)]*F_v(:,:,1)';
for i=2:(length(t))-1
    F_x(:,:,i) = [1 0 -delta_d(i) * sin(o(i)); 0 1 delta_d(i) * cos(o(i));
0 0 1];
    F_v(:,:,i) = [cos(o(i)) 0; sin(o(i)) 0; 0 1];
    P(:,:,i) = F_x(:,:,i)*P(:,:,i-1)*F_x(:,:,i)' + F_v(:,:,i)*[V(1) 0; 0
V(2,2)]*F_v(:,:,i)';
end
```

Covariance evolution

```
for i=2:length(P)
    a(i)=sqrt(det(P(:,:,i)));
end

figure
grid on
plot((0:0.02:3002*0.02),a)
```

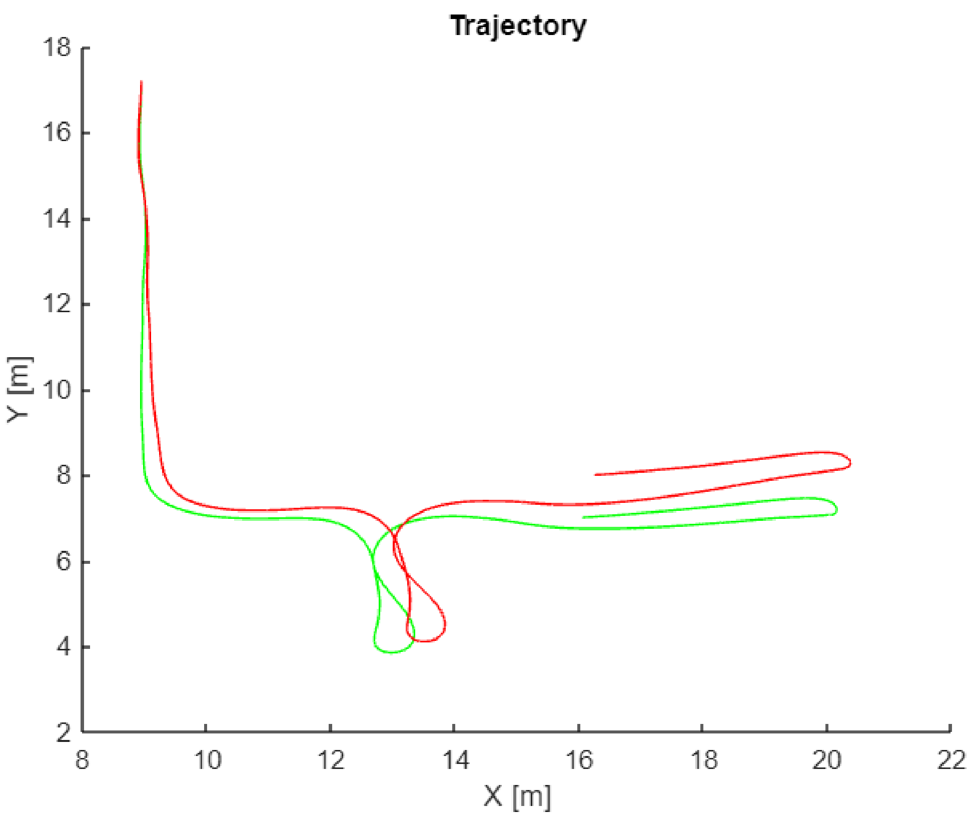
```
Warning: Imaginary parts of complex X and/or Y arguments ignored.
```



```
title ('Covariance evolution',"FontSize",20)
```

2.a) x,y poses for both trajectories: theoric and estimated

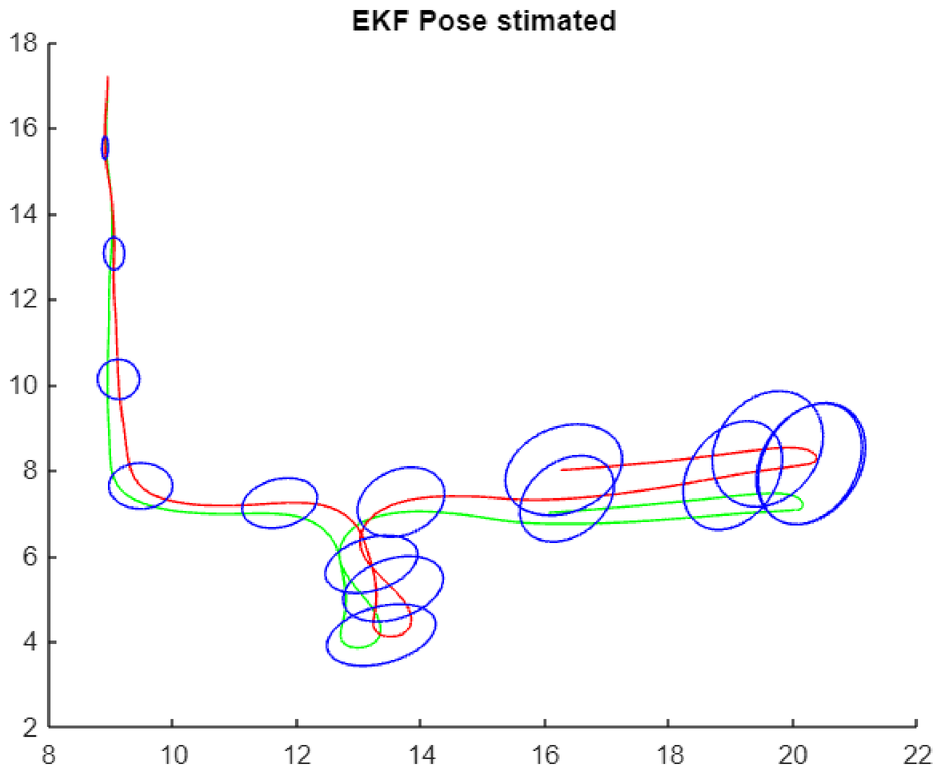
```
figure
hold on
title('Trajectory')
xlabel ('X [m]')
ylabel ('Y [m]')
plot(x,y,'g')
plot(x_n,y_n,'r')
```



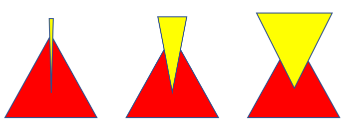
2.b) ellipses representing x,y uncertanty. Do it every 15-20 poses.

```
figure
hold on
plot(x,y,'g')
plot(x_n,y_n,'r')

hold on
for i=1:round(length(t)/15):length(t)
    plot_ellipse(P(1:2,1:2,i),[x_n(i), y_n(i)],'b');
    title('EKF Pose stimated');
end
```

```
Warning: Matrix is singular and may not have a square root.
```



2.c) represent uncertanty in orientation by adding a isosceles triange in front of the robot the base

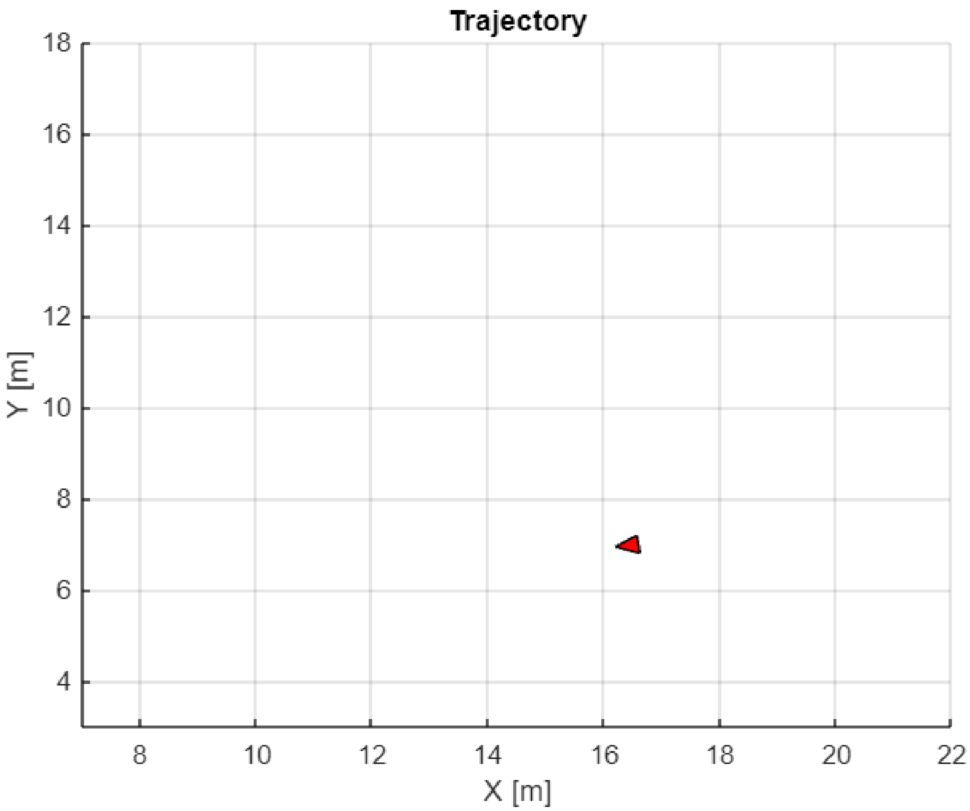


The robot will be represented by a triangle: Robot= [0 -0.2 0 1;0.4 0 0 1;0 0.2 0 1]

```
Robot = [0 -0.2 0 1;0.4 0 0 1;0 0.2 0 1];

totalFrames = length(x);

F = zeros(totalFrames);

% Create waitbar
h = waitbar(0, 'Processing Frames...');

for i=1:totalFrames
    clf
    figure(1)
    grid on
    hold on
    title('Trajectory')
    xlabel ('X [m]')
```

```
    ylabel ('Y [m]')
    xlim([7,22])
    ylim([3,18])
    plot(x,y,'g')
    plot(x_n,y_n,'r')

    robotPosition = (transl(x(i),y(i),0)*trotz(o(i))*Robot')';
    robotTriangle = polyshape(robotPosition(:,1),robotPosition(:,2));
    plot(robotTriangle,'FaceColor','r','FaceAlpha',1);
    u = (sin(P(3,3,i)/2)+0.0001)*20;
    Cone = [0.1 0 0 1; 0.5 u 0 1; 0.5 -u 0 1];
    conePosition = (transl(x(i),y(i),0)*trotz(o(i))*Cone')';
    coneTriangle = polyshape(conePosition(:,1),conePosition(:,2));
    plot(coneTriangle,'FaceColor','y','FaceAlpha',1);
    drawnow;
    F(i) = getframe(gcf);

    % Update the waitbar
    waitbar(i / totalFrames, h, sprintf('Processing Frame %d of %d', i,
totalFrames));

end

% Close waitbar
close(h);

vidwriter = VideoWriter('RobotUncertainityAngle.mp4','MPEG-4');
vidwriter.FrameRate = 50;
open(vidwriter);
for i=1:length(F)
    writeVideo(vidwriter, F(i));
end
close(vidwriter)


% Robot = [0 -0.2 0 1;0.4 0 0 1;0 0.2 0 1];
% robotTriangle = polyshape(Robot(:,1),Robot(:,2));
%
% totalFrames = size(polar_laser_data, 1) * 20 - 1;
% h = waitbar(0, 'Processing Frames');
%
% for i=1:totalFrames
%     clf
%     figure(1)
%     grid on
%     hold on
%     title('Trajectory')
%     xlabel ('X [m]')
%     ylabel ('Y [m]')
%     xlim([7,22])
```

```
%     ylim([3,18])
%     % plot(x_c,y_c,'-b')
%
%     % robotPose =
transl(log2.CorrectedPositionX(i),log2.CorrectedPositionY(i),0)*...
%     % trotz(log2.CorrectedPositionO(i));
%
%     robotPosition = (robotPose*Robot')';
%     robotTriangle = polyshape(robotPosition(:,1),robotPosition(:,2));
%     plot(robotTriangle,'FaceColor','r','FaceAlpha',1);
%
%     if mod(i,10) == 0
%         res = [];
%         ang = linspace(-120*pi/180,120*pi/180,682);
%         [pointsX, pointsY] = pol2cart(ang, ...
%             polar_laser_data(floor(i/(0.4/time))+1,2:683)/1000);
%         pointsL = [pointsX; pointsY];
%         idx = 1;
%         for j=1:682
%             if(pointsL(1,j) ~= 0 || pointsL(2,j) ~= 0)
%                 res(:,idx) = pointsL(:,j);
%                 idx = idx + 1;
%             end
%         end
%         if(~isempty(res))
%             scatter(res(1,:),res(2,:),2,'filled','MarkerFaceColor',[1 0
0]);
%         end
%         drawnow;
%     end
%
%     F2(i) = getframe(gcf);
%
%     % Update the waitbar
%     waitbar(i / totalFrames, h, sprintf('Processing Frame %d of %d', i,
totalFrames));
% end
```




```
Error using waitbar
The second argument must be a message character vector or a handle to an existing waitbar.
```

```
% Close the waitbar
close(h);

vidwriter = VideoWriter('RobotReferenceFrame.mp4','MPEG-4');
vidwriter.FrameRate = 50;
open(vidwriter);
for i=1:length(F2)
    writeVideo(vidwriter, F2(i));
end
close(vidwriter)
```

Driving the Robot (20%)

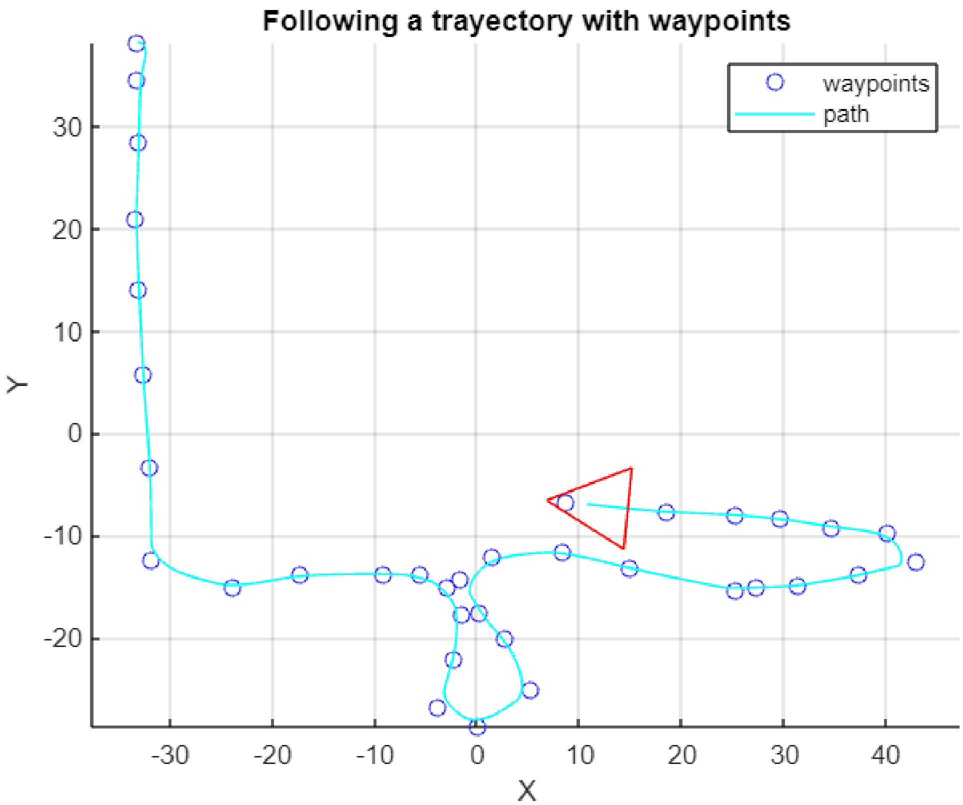
Based on what you learn in motion arquitectures use the Goint2point for driving the robot. Use 'frontend.m' function to introduce way points such to recreate a trajectory similar to the past section.

Make a video displaying both trajectories: estimated and theoric. Add the ellipses to visualize uncertanty.

Notice that in this exercise the trajectoryies appear as the robot moves.

```
% % Add your code here
% load("way_points_2.mat")
%
% % Calculate all the intermidiate points to the
% n_points= size(wp, 2);
```

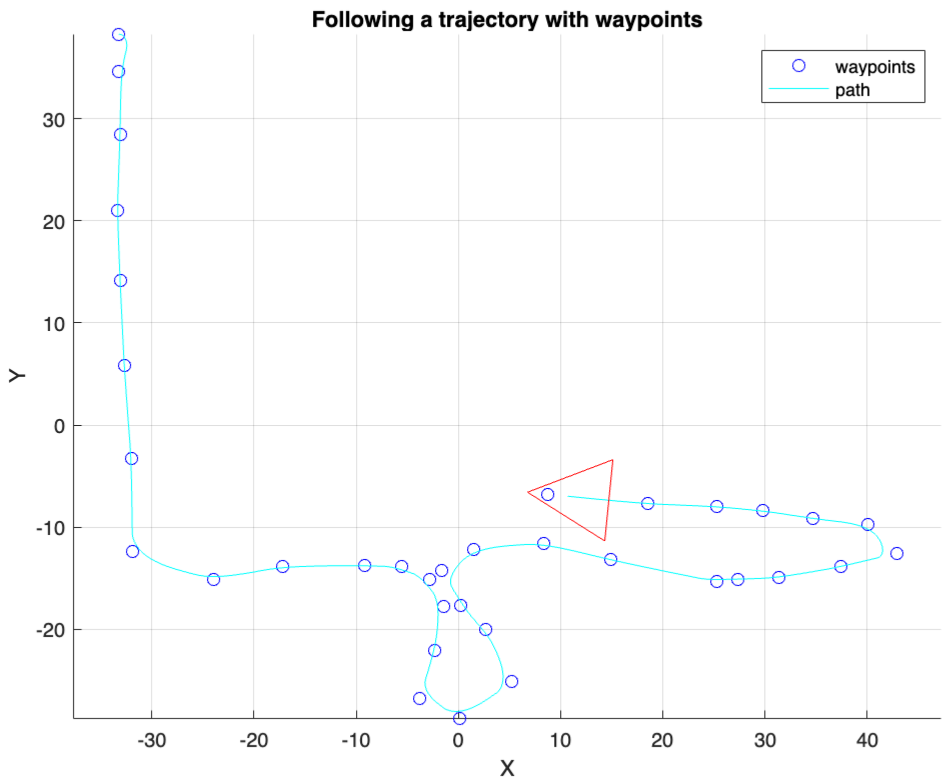
```
% startPose = wp(:,1)';
% startPose(3) = 0 ;
% poses = [];
% figure
% %Drawing all the waypoints
% scatter(wp(1,:), wp(2,:),'Marker','o','MarkerEdgeColor','b');
% title('Following a trayectory with waypoints');
% hold on;
% axis equal
% grid
% xlabel("X");
% ylabel("Y");
%
% Robot.V = [0 -0.2 0;
%            0.4 0 0;
%            0 0.2 0;];
% Robot.F = [1,2,3];
% Robot.V = Robot.V * 20;
% fig_robot = [];
% Kv = 0.9; % Velocity Gain
% Kh = 4; % Head Gain
% minStopDistance = 2;
% for i = 2:n_points;
%     goal = wp(:,i)';
%     poses_current = goToPoint(goal,startPose,Kv,Kh,minStopDistance);
%     for j = 1:size(poses_current,1)-1
%         pose_matrix =
transl(poses_current(j,1),poses_current(j,2),0)*trotz(poses_current(j,3));
%         CG = (max(Robot.V) + min(Robot.V))/2;
%         T = pose_matrix*transl(-CG);
%         aux = [Robot.V ones(length(Robot.V'),1)]' ;
%         robot = (T * aux)';
%         robot(:,4) = [];
%         delete(fig_robot);
%         fig_robot=patch("Faces",Robot.F,"Vertices",robot, 'FaceAlpha',
0, ...
%                  'EdgeColor',   [1,0,0]);
%         plot(poses_current(j:j+1,1),poses_current(j:j+1,2),"Color",'c');
%
% %       pause(0.05);
%     end
%     pause(0.05);
%     startPose = poses_current(end,:);
%     poses  = [poses; poses_current];
%
% end
% legend('waypoints','path');
```




```
load("way_points_2.mat")

% Calculate all the intermediate points
n_points = size(wp, 2);
startPose = wp(:,1)';
startPose(3) = 0;
poses = [];

Robot.V = [0 -0.2 0;
           0.4 0 0;
           0 0.2 0;];
Robot.F = [1,2,3];
Robot.V = Robot.V * 20;
fig_robot = [];
Kv = 0.9; % Velocity Gain
Kh = 4; % Head Gain
minStopDistance = 2;


% % Define parameters for noise
% meanNoise = 1;                  % Mean of the noise
% stdDevNoise = 0.5;              % Standard deviation of the noise
%
% % Precalculate all poses with noise
% for i = 2:n_points
```

```
%     goal = wp(:,i)';
%     poses_current = goToPoint(goal, startPose, Kv, Kh, minStopDistance);
%
%     % Add noise to each pose
%     noise = stdDevNoise * randn(size(poses_current));
%     poses_current = poses_current + noise;
%
%     poses = [poses; poses_current];
%     startPose = poses_current(end,:);
% end

bar = waitbar(0, 'Calculating poses...');
% Precalculate all poses
for i = 2:n_points
    goal = wp(:,i)';
    poses_current = goToPoint(goal, startPose, Kv, Kh, minStopDistance);
    poses = [poses; poses_current];
    startPose = poses_current(end,:);
    % Update waitbar
    waitbar(i/n_points, bar, sprintf('Processing point %d of %d', i,
n_points));
end
close(bar); % Close the waitbar when the loop is finished
% Plotting the trajectory and waypoints
figure
scatter(wp(1,:), wp(2,:), 'Marker', 'o', 'MarkerEdgeColor', 'b');
hold on;
axis equal
grid
xlabel("X");
ylabel("Y");
title('Following a trajectory with waypoints');

% Plotting the precalculated poses
fig_robot = [];
n_poses = size(poses,1)-1;
for j = 1:n_poses
    pose_matrix = transl(poses(j,1), poses(j,2), 0) * trotz(poses(j,3));
    CG = (max(Robot.V) + min(Robot.V))/2;
    T = pose_matrix * transl(-CG);
    aux = [Robot.V ones(length(Robot.V'),1)]';
    robot = (T * aux)';
    robot(:,4) = [];
    delete(fig_robot);
    fig_robot = patch("Faces", Robot.F, "Vertices", robot, 'FaceAlpha', 0,
'EdgeColor', [1,0,0]);
    plot(poses(j:j+1,1), poses(j:j+1,2), "Color", 'c');
    if mod(j, 10) == 0
        pause(0.01); % Pause after every 10 poses
    end
```

```
end

legend('waypoints', 'path');
```



Localization (30%)

While driving the Robot in the last section Localize the Robot by using the Similarity Transform.

Visit again the folder 11_Localization for inspiration.

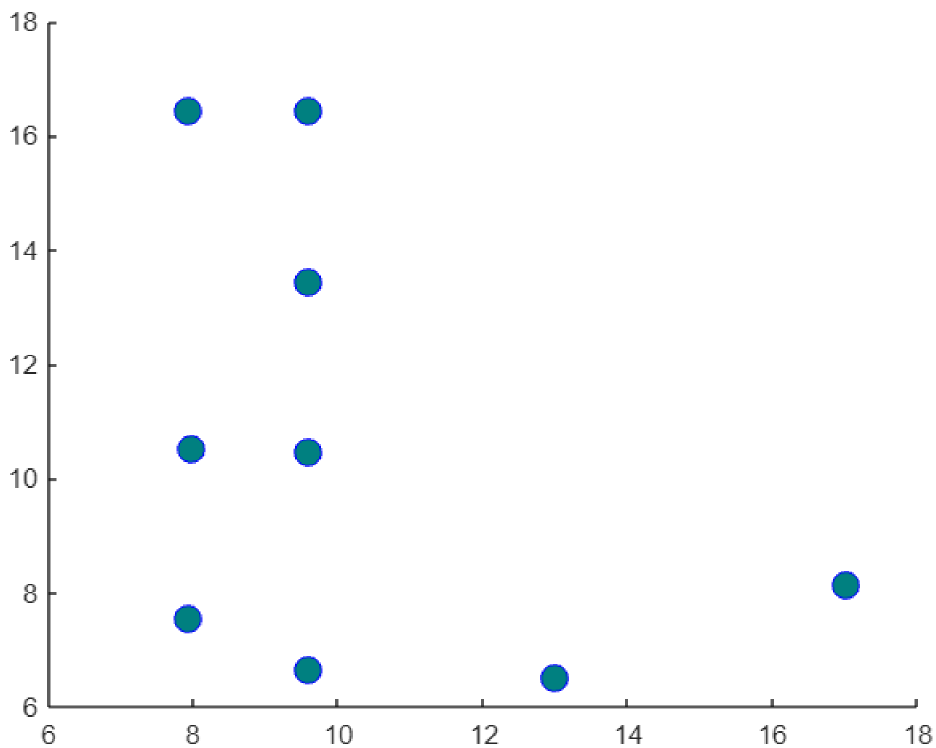
Land Marks

Use the given Land Marks. They are known. They can be extracter from laser data, there are easy algorithms for finding they, like corner detection, etc ...

```
Lmk= [7.934 16.431 0 1;...
    9.583 16.431 0 1;...
    9.584 13.444 0 1;...
    9.584 10.461 0 1;...
    7.973 10.534 0 1;...
    7.934  7.547 0 1;...
    9.584  6.654 0 1;...
    13.001  6.525 0 1;...
    17.007  8.136 0 1];
```

Plot Land Marks

```
clf
hold on
sz = 100;
s=scatter(Lmk(:,1),Lmk(:,2),sz);
s.LineWidth = 0.6;
s.MarkerEdgeColor = 'b';
s.MarkerFaceColor = [0 0.5 0.5];
```




```
TimeStamp = t;
EstimatedNoisyX = x_n';
EstimatedNoisyY = y_n';
EstimatedNoisyO = o_n';
NumberLandmarksReal = sum(((l_s_d~=0) | (l_s_d~=0)),2);
NumberLandmarksLog = [NumberLandmarksReal; 0; 0; 0];
log = table(TimeStamp,EstimatedNoisyX,EstimatedNoisyY,EstimatedNoisyO,...
    NumberLandmarksLog)
```

log = 3004×5 table

...

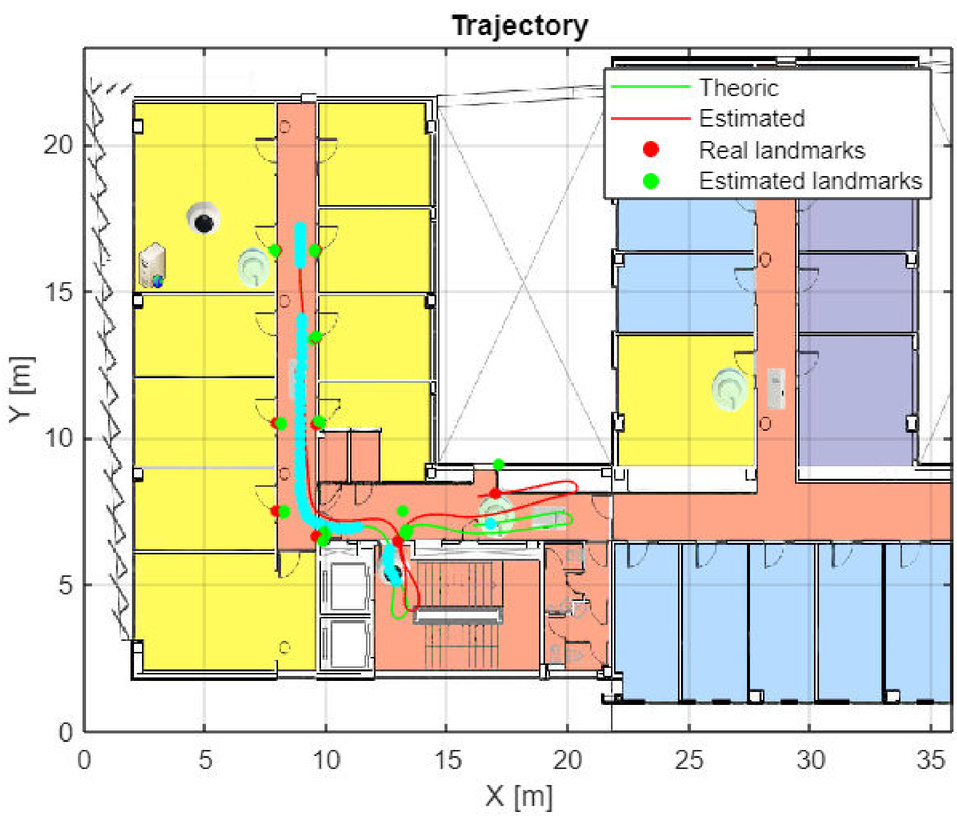
	TimeStamp	EstimatedNoisyX	EstimatedNoisyY	EstimatedNoisyO
1	0	8.9500	17.2000	-1.5708
2	0.0200	8.9500	17.1989	4.7155
3	0.0400	8.9500	17.1953	4.7143

	TimeStamp	EstimatedNoisyX	EstimatedNoisyY	EstimatedNoisyO
4	0.0600	8.9500	17.1998	4.7129
5	0.0800	8.9500	17.1981	4.7100
6	0.1000	8.9500	17.1974	4.7098
7	0.1200	8.9500	17.2000	4.7096
8	0.1400	8.9500	17.2009	4.7089
9	0.1600	8.9500	17.2002	4.7073
10	0.1800	8.9500	17.1931	4.7039
11	0.2000	8.9499	17.1875	4.7100
12	0.2200	8.9499	17.1902	4.7130
13	0.2400	8.9499	17.1841	4.7122
14	0.2600	8.9499	17.1819	4.7089

⋮

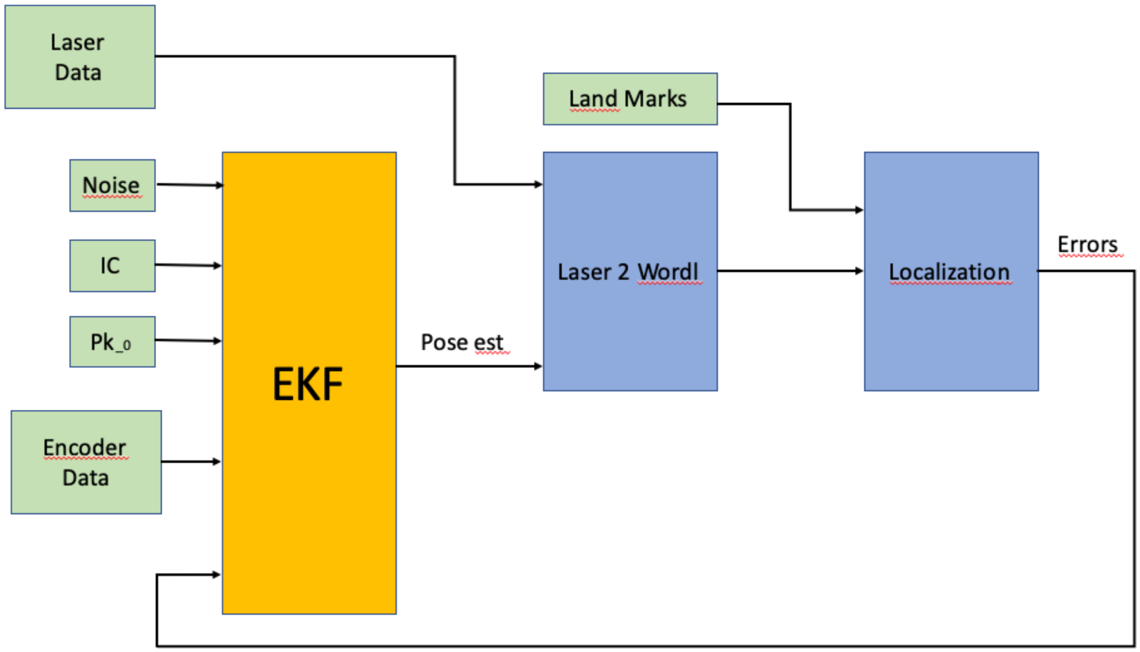
```
clf
figure

I=imread('Enviroment.png');
x_ima=[0 35.9];
y_ima=[23.31 0];
image(I,'XData',x_ima,'YData',y_ima);
axis xy;
plotTrajectories(x,y,x_n,y_n);

LandMark= lmk';
for i=1:length(l_s_b)
    Robot_pose_est = transl(x_n(i),y_n(i),0)*trotz(o_n(i));
    if log.NumberLandmarksLog(i) > 1
        ld = l_s_d(i,:);
        lb = l_s_b(i,:);
        [lmx, lmy] = pol2cart(lb,ld);
        lmw = [];
        A = [];
        B = [];
        idx = 1;
        for j=1:9
            if lmx(j) ~= 0 || lmy(j) ~= 0
                lmw(idx,:) = Robot_pose_est*[lmx(j); lmy(j); 0; 1];
                scatter(LandMark(1,j),LandMark(2,j),20, 'r','filled');
                scatter(lmw(idx,1),lmw(idx,2),20, 'g','filled');

                A = [A;[LandMark(1,j),LandMark(2,j),1,0]];
                A = [A;[LandMark(2,j),-LandMark(1,j),0,1]];
```

```
                B = [B; lmw(idx,1); lmw(idx,2)];
                idx = idx + 1;
            end
        end
        X = (A'*A)\(A'*B);
        tx_ST = X(3);
        ty_ST = X(4);
        alpha_ST = atan2(X(2),X(1));
        Robot_m=transl(Robot_pose_est);
        Robot_error= transl(-tx_ST,-ty_ST,0)*trotz(alpha_ST)*[Robot_m;1];
        scatter(Robot_error(1),Robot_error(2),20, 'cyan','filled');
    end

end
legend('Theoric','Estimated','Real landmarks','Estimated landmarks')
```



Correct the noisy trajectory.

Pay attention to the relationship of the variables



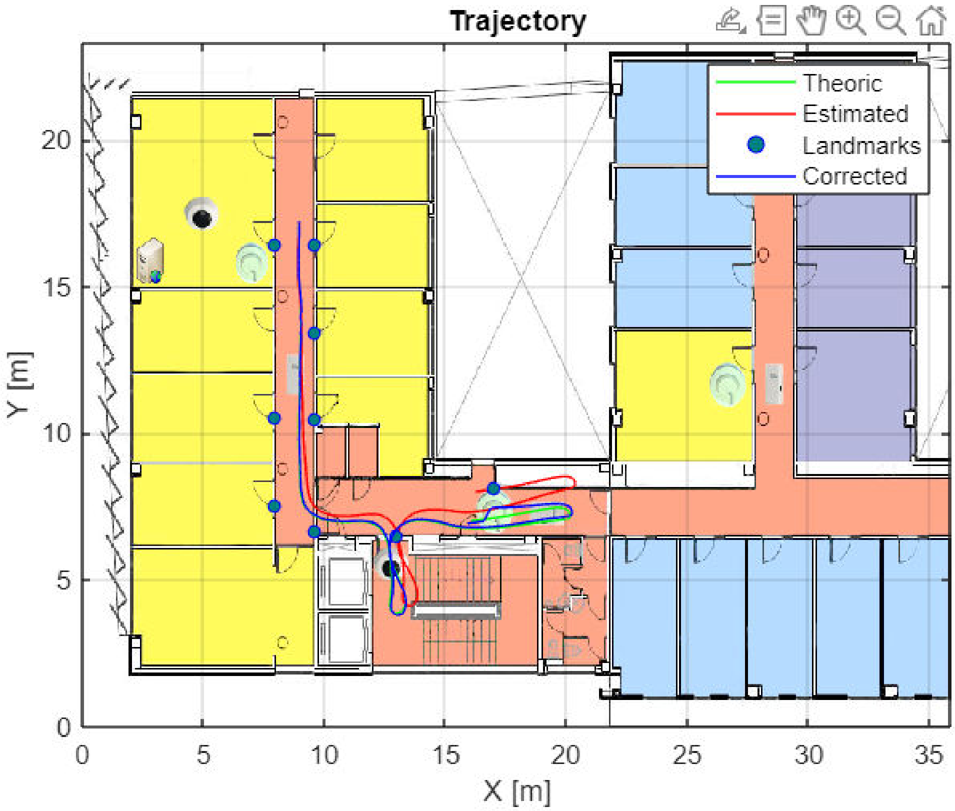
Update the estimated covarianze matrix by the sensor, knowing that the Laser scanner has and acuraccy 4 mm with a standard deviation of 0.2 mm.

1.- Display in a figure: the map, theoric trajectory (no noise) and the corrected trajectory.

2.- Make a 'log' with the following columns: estimated noisy pose, corrected position, number of Land-marks seen, and the errors and the covariance matrix Pk.

```
clf
figure
I=imread('Enviroment.png');
x_ima=[0 35.9];
y_ima=[23.31 0];
image(I,'XData',x_ima,'YData',y_ima);
axis xy
plotTrajectories(x,y,x_n,y_n);
lmk= [7.934 16.431 0 1;...
    9.583 16.431 0 1;...
    9.584 13.444 0 1;...
    9.584 10.461 0 1;...
    7.973 10.534 0 1;...
    7.934 7.547 0 1;...
    9.584 6.654 0 1;...
    13.001 6.525 0 1;...
    17.007 8.136 0 1];
hold on
s=scatter(lmk(:,1),lmk(:,2),20);
s.LineWidth = 0.6;
s.MarkerEdgeColor = 'b';
s.MarkerFaceColor = [0 0.5 0.5];
LandMark= lmk';
```

```
x_c = [];
y_c = [];
o_c = [];
x_c(1) = x_n(1);
y_c(1) = y_n(1);
o_c(1) = o_n(1);
Position = [];
for i=1:length(l_s_b)
    Robot_pose_est = transl(x_c(i),y_c(i),0)*trotz(o_c(i));
    if log.NumberLandmarksLog(i) > 1
        ld = l_s_d(i,:);
        lb = l_s_b(i,:);
        [lmx, lmy] = pol2cart(lb,ld);
        lmw = [];
        A = [];
        B = [];
        idx = 1;
        for j=1:9
            if lmx(j) ~= 0 || lmy(j) ~= 0
                lmw(idx,:) = Robot_pose_est*[lmx(j); lmy(j); 0; 1];

                A = [A;[LandMark(1,j),LandMark(2,j),1,0]];
                A = [A;[LandMark(2,j),-LandMark(1,j),0,1]];
                B = [B; lmw(idx,1); lmw(idx,2)];
                idx = idx + 1;
            end
        end
        X = (A'*A)\(A'*B);
        tx_ST = X(3);
        ty_ST = X(4);
        alpha_ST = atan2(X(2),X(1));
        newPoint = transl(-tx_ST,-ty_ST,0)*trotz(alpha_ST)*[x_c(i) y_c(i) 0
1]';
        x_c(i) = newPoint(1);
        y_c(i) = newPoint(2);
        o_c(i) = alpha_ST+o_c(i);
    end
    Position(:,i) = [x_c(i),y_c(i),0]';

    x_c(i+1) = x_c(i)+delta_d_n(i)*cos(o_c(i));
    y_c(i+1) = y_c(i)+delta_d_n(i)*sin(o_c(i));
    o_c(i+1) = mod(o_c(i)+delta_t_n(i),2*pi);
end

plot(Position(1,1:end),Position(2,1:end),'b');
legend('Theoric','Estimated','Landmarks','Corrected')
```




```
TimeStamp = t(1:end-3);
EstimatedNoisyX = x_n(1:end-3)';
EstimatedNoisyY = y_n(1:end-3)';
EstimatedNoisyO = o_n(1:end-3)';

CorrectedPositionX = x_c';
CorrectedPositionY = y_c';
CorrectedPositionO = o_c';
log2 = table(TimeStamp,EstimatedNoisyX,EstimatedNoisyY,EstimatedNoisyO,...

CorrectedPositionX,CorrectedPositionY,CorrectedPositionO,NumberLandmarksReal
)
```

log2 = 3001×8 table

...

	TimeStamp	EstimatedNoisyX	EstimatedNoisyY	EstimatedNoisyO
1	0	8.9500	17.2000	-1.5708
2	0.0200	8.9500	17.1989	4.7155
3	0.0400	8.9500	17.1953	4.7143
4	0.0600	8.9500	17.1998	4.7129
5	0.0800	8.9500	17.1981	4.7100
6	0.1000	8.9500	17.1974	4.7098

	TimeStamp	EstimatedNoisyX	EstimatedNoisyY	EstimatedNoisyO
7	0.1200	8.9500	17.2000	4.7096
8	0.1400	8.9500	17.2009	4.7089
9	0.1600	8.9500	17.2002	4.7073
10	0.1800	8.9500	17.1931	4.7039
11	0.2000	8.9499	17.1875	4.7100
12	0.2200	8.9499	17.1902	4.7130
13	0.2400	8.9499	17.1841	4.7122
14	0.2600	8.9499	17.1819	4.7089

⋮

Mapping (10%)

Make a movie of laser data in Robot reference frame. See the video of ATENEA: Movie of the Laser Data seen in Robot Reference FrameURL

Make a video of laser data in Wordl Reference frame. Use here the code of the last TODO Lab about laser data.

Display laser data every 2.5 m and erasing the previous walls after 200ms for better understanding.

See the video: '3_mapping.mp4' for inspiration

Robot Reference Frame:

```
Robot = [0 -0.2 0 1;0.4 0 0 1;0 0.2 0 1];
robotTriangle = polyshape(Robot(:,1),Robot(:,2));

totalFrames = size(polar_laser_data, 1) * 20 - 1;
h = waitbar(0, 'Processing Frames');

for i=1:totalFrames
    clf
    figure(1)
    grid on
    hold on
    xlim([-0.4 1])
    ylim([-1.5 1.5])

    plot(robotTriangle,'FaceColor','r','FaceAlpha',1);

    ang = linspace(-120*pi/180,120*pi/180,682);
    [pointsX, pointsY] = pol2cart(ang, ...
        polar_laser_data(floor(i/(0.4/time))+1,2:683)/1000);
```

```
    pointsL = [pointsX; pointsY];
    idx = 1;
    for j=1:682
        if(pointsL(1,j) ~= 0 || pointsL(2,j) ~= 0)
            res(:,idx) = pointsL(:,j);
            idx = idx + 1;
        end
    end
    scatter(res(1,:),res(2,:),2,'filled','MarkerFaceColor',[1 0 0]);

    F2(i) = getframe(gcf);

    % Update the waitbar
    waitbar(i / totalFrames, h, sprintf('Processing Frame %d of %d', i,
totalFrames));
end
% Close the waitbar
close(h);

vidwriter = VideoWriter('RobotReferenceFrame.mp4','MPEG-4');
vidwriter.FrameRate = 50;
open(vidwriter);
for i=1:length(F2)
    writeVideo(vidwriter, F2(i));
end
close(vidwriter)
```

Robot World reference frame:

```
Robot = [0 -0.2 0 1;0.4 0 0 1;0 0.2 0 1];
walls = [];
for i=1:size(polar_laser_data,1)*20-1
    if mod(i,10) == 0
        walls = [];
    end

    robotPose =
transl(log2.CorrectedPositionX(i),log2.CorrectedPositionY(i),0)*...
        trotz(log2.CorrectedPositionO(i));
    if log2.NumberLandmarksReal(i) > 0
        ang = linspace(-120*pi/180,120*pi/180,682);

        [pointsX, pointsY] = pol2cart(ang, ...
            polar_laser_data(floor(i/(0.4/time))+1,2:683)/1000);
        pointsL = [pointsX; pointsY; zeros(1,682); ones(1,682)];
        idx = 1;
        for j=1:682
            if(pointsL(1,j) ~= 0 || pointsL(2,j) ~= 0)
                walls(:,idx) = robotPose*pointsL(:,j);
```

```
                idx = idx + 1;
            end
        end
    end
    clf
    figure(1)
    grid on
    hold on
    title('Trajectory')
    xlabel ('X [m]')
    ylabel ('Y [m]')
    xlim([7,22])
    ylim([3,18])
    plot(x_c,y_c,'-b')


    robotPosition = (robotPose*Robot')';
    robotTriangle = polyshape(robotPosition(:,1),robotPosition(:,2));
    plot(robotTriangle,'FaceColor','r','FaceAlpha',1);

    if(~isempty(walls))
        scatter(walls(1,:),walls(2,:),2,'filled','MarkerFaceColor',[1 0 0]);
    end
    drawnow;
    F(i) = getframe(gcf);
end


% vidwriter = VideoWriter('RobotMapping.mp4','MPEG-4');
% vidwriter.FrameRate = 50;
% open(vidwriter);
% for i=1:length(F)
% writeVideo(vidwriter, F(i));
% end
% close(vidwriter)
```

Occupancy grid (30%)

Use Breshehan algorithm to build the map. Do it only when Land Marks are avalaible and the trajectory have been corrected.

Use the idea behind the line tracing: Visit: https://es.wikipedia.org/wiki/Algoritmo_de_Bresenham

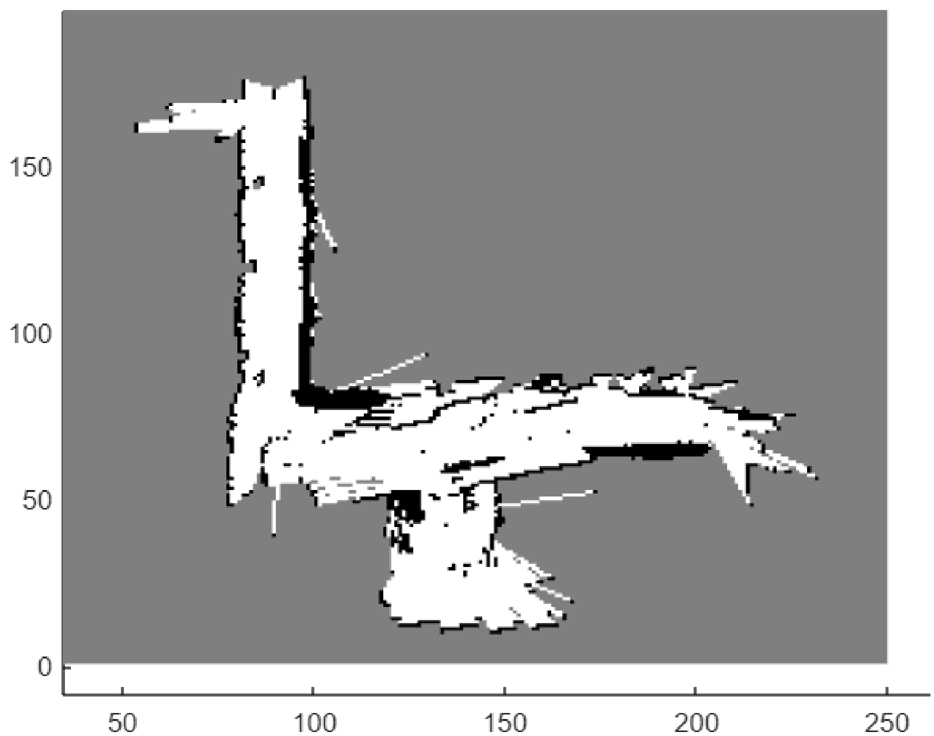
See: Mapping.mlx and '4_occupancy.mp4' for inspiration

```
vidwriter = VideoWriter('Occupancy.avi','Motion JPEG AVI');
vidwriter.FrameRate = 3;
open(vidwriter);
walls = []
```

```
walls =

     []
```

```
A=ones(250,250);
clear F

bar = waitbar(0, 'Processing Frames');
totalIterations = (size(polar_laser_data, 1) - 1) * 20;

for i=20:20:size(polar_laser_data,1)*20-1
    walls = [];
    robotPose =
transl(log2.CorrectedPositionX(i),log2.CorrectedPositionY(i),0)*...
        trotz(log2.CorrectedPositionO(i));
    if log2.NumberLandmarksReal(i) > 0
        ang = linspace(-120*pi/180,120*pi/180,682);
        [pointsX, pointsY] = pol2cart(ang,...
            polar_laser_data(floor(i/(0.4/time))+1,2:683)/1000);
        pointsL = [pointsX; pointsY; zeros(1,682); ones(1,682)];
        idx = 1;
        for j=1:682
            if(pointsL(1,j) ~= 0 || pointsL(2,j) ~= 0)
                walls(:,idx) = robotPose*pointsL(:,j);
                idx = idx + 1;
            end
        end
    end
    clf

    figure(1)
    hold on

    for j=1:length(walls)

        rob_position = transl(robotPose)*10;
        destination = round(walls(1:2,j)*10);

        rrob_position = round( rob_position(1:2));
        [l_x, l_y] = bresenham(rrob_position(1), rrob_position(2) ,
destination(1), destination(2));
        L=size(l_x,1);

        for k=1:L
            A(l_y(k),l_x(k)) = 2;
        end
        A(destination(2),destination(1)) = 0;

    end
    A(round(rob_position(2)),round(rob_position(1))) = 0;
```

```
    h = pcolor(A);
    set(h, 'EdgeColor', 'none');
    colormap(gray(3))
    grid off
    drawnow
    writeVideo(vidwriter,getframe(gcf))
    A(round(rob_position(2)),round(rob_position(1))) = 2;

   % Update progress bar
    waitbar(i / totalIterations, bar, sprintf('Processing Frame %d of %d',
i, totalIterations));

end
```




```
% Close waitbar
close(bar);
close(vidwriter)
```

```
function plotTrajectories(x,y,xn,yn)

grid on
hold on
title('Trajectory')
xlabel ('X [m]')
ylabel ('Y [m]')
plot(x,y,'g')
```

```
plot(xn,yn,'r')

end


function [poses] = goToPoint(goal,startPose,Kv,Kh,minStopDistance)
%   Input:
%     goal - goal point
%     startPose - vehicles' start pose
%     Kv - Velocity Gain
%     Kh - % Head Gain
%     minStopDistance - minStopDistance to the goal point to consider that
%     we have arrived to the goal.
%   Output: all the poses from startPose until it arrive to a less than
%   minStopDistance to goal

    I_kine = @(v_x, psi,r,S) ...
    [(1/r)*v_x+ (1/r)*S*psi (1/r)*v_x-(1/r)*S*psi];

    odo = @(phi_r, phi_l,r,S,ts) ...
    [(1/2)*r*(phi_r+phi_l)*ts (r/(2*S))*(phi_r-phi_l)*ts];

    Pose_int=@(X_ant,odo) ...
    [X_ant(1)+odo(1)*cos(X_ant(3)) ...
     X_ant(2)+odo(1)*sin(X_ant(3)) ...
     X_ant(3)+odo(2)];

    r = 0.1; % wheels radius
    S = 0.26; % half of the distance between the wheels' center
    ts = 0.02;% sample time

    currentPose = startPose;
    stop = false;
    while (~stop)
    currentdiff = goal - currentPose(end,[1,2]);
    %Velocity
    %distance to goal or distance error
    throttle = sqrt(currentdiff(1)^2 + currentdiff(2)^2);

    if throttle < minStopDistance
        stop = true;
    else
        velocity = throttle *  Kv;
        %Psi
        %heading angle to goal
        steering = atan2(currentdiff(2),currentdiff(1));
        %heading error
        anglesdiff = angdiff(steering,currentPose(end,3));
        psi = anglesdiff * Kh;
        %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

```
        %%%%% Review %%%%%%
        % in theory [phi_r phi_l] = I_kine(vx,Psi,r,S);
        angular_velocitys = I_kine(velocity,psi,r,S);
        % However when angular_velocitys(1) is asign to the phi_r,
        % the robot goes in the oposite direction.
        phi_l = angular_velocitys(2);
        phi_r = angular_velocitys(1);
        %%%%%%%%%%%%%%%%%%%%%%%%%%%%%
        deltas = odo(phi_r,phi_l,r,S,ts);
        noise_std = 0.002;
        delta_d = deltas(1);
        delta_th = deltas(2);
        %Calculating new pose
        currentPose = [currentPose; Pose_int(currentPose(end,:),
[delta_d,delta_th])];
     end
    end
    poses = currentPose;
end


% function [poses] = goToPoint(goal,startPose,Kv,Kh,minStopDistance,
noise_std)
% %   Input:
% %     goal - goal point
% %     startPose - vehicles' start pose
% %     Kv - Velocity Gain
% %     Kh - % Head Gain
% %     minStopDistance - minStopDistance to the goal point to consider that
% %     we have arrived at the goal.
% %     noise_std - standard deviation of the noise to be added to the
odometry
% %   Output: all the poses from startPose until it arrives at a distance
less than
% %   minStopDistance to the goal.
%
%     I_kine = @(v_x, psi,r,S) ...
%     [(1/r)*v_x+ (1/r)*S*psi (1/r)*v_x-(1/r)*S*psi];
%
%     odo = @(phi_r, phi_l,r,S,ts) ...
%     [(1/2)*r*(phi_r+phi_l)*ts (r/(2*S))*(phi_r-phi_l)*ts];
%
%     Pose_int=@(X_ant,odo) ...
%     [X_ant(1)+odo(1)*cos(X_ant(3)) ...
%      X_ant(2)+odo(1)*sin(X_ant(3)) ...
%      X_ant(3)+odo(2)];
%
%     r = 0.1; % wheels radius
%     S = 0.26; % half of the distance between the wheels' center
%     ts = 0.02; % sample time
```

```
%
%     currentPose = startPose;
%     stop = false;
%     while (~stop)
%         currentdiff = goal - currentPose(end,[1,2]);
%         % Velocity
%         % distance to goal or distance error
%         throttle = sqrt(currentdiff(1)^2 + currentdiff(2)^2);
%
%         if throttle < minStopDistance
%             stop = true;
%         else
%             velocity = throttle *  Kv;
%             % Psi
%             % heading angle to goal
%             steering = atan2(currentdiff(2),currentdiff(1));
%             % heading error
%             anglesdiff = angdiff(steering,currentPose(end,3));
%             psi = anglesdiff * Kh;
%
%             %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%             %%%%% Review %%%%%%
%             % in theory [phi_r phi_l] = I_kine(vx,Psi,r,S);
%             angular_velocitys = I_kine(velocity,psi,r,S);
%             % However when angular_velocitys(1) is assigned to phi_r,
%             % the robot goes in the opposite direction.
%             phi_l = angular_velocitys(2);
%             phi_r = angular_velocitys(1);
%             %%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%
%             deltas = odo(phi_r,phi_l,r,S,ts);
%             delta_d = deltas(1);
%             delta_th = deltas(2);
%
%             % Add noise to odometry
%             t = 0:ts:(length(currentPose)-1)*ts;
%             delta_d_n = delta_d + randn(length(t)-1,1)*noise_std;
%             delta_th_n = delta_th + randn(length(t)-1,1)*noise_std;
%
%
%             currentPose = [currentPose; Pose_int(currentPose(end,:),
[delta_d_n, delta_th_n])];
%
%         end
%     end
%     poses = currentPose;
% end
%
```