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Team: **G11A**

Shared Link with the teacher: https://drive.matlab.com/sharing/c96143d6-d207-454e-80b3-7df7dd945dc7/

Table of Contents

Load and visualize data

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

Tf = 60.08;
Ts = 0.02;
W = 0.52;
Gear_ratio = 100;
r = 0.1;

R_inc = right_angular_speed(:, 2) / Gear_ratio * r * Ts;
L_inc = left_angular_speed(:, 2) / Gear_ratio * r * Ts;
R_acu = [right_angular_speed(:, 1), cumsum(R_inc)];
L_acu = [left_angular_speed(:, 1), cumsum(L_inc)];
```

Plotting encoders data with respect time

```
t=R_acu(:,1)
```

```
t = 3004×1
         0
    0.0200
    0.0400
```

```
    0.0600
    0.0800
    0.1000
    0.1200
    0.1400
    0.1600
    0.1800
      ⋮
```

```
t=(0:Ts:Tf-Ts)'
```

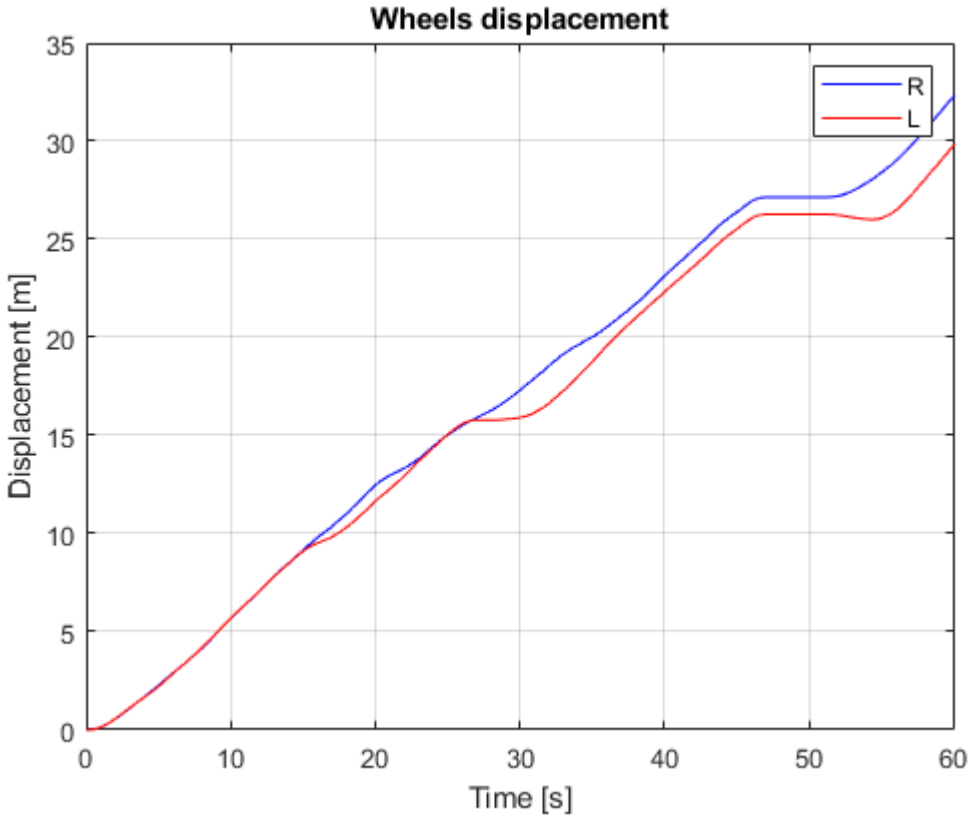
```
t = 3004×1
         0
    0.0200
    0.0400
    0.0600
    0.0800
    0.1000
    0.1200
    0.1400
    0.1600
    0.1800
      ⋮
```

```
t=linspace(0,Tf,length(R_acu(:,2)))'
```

```
t = 3004×1
         0
    0.0200
    0.0400
    0.0600
    0.0800
    0.1000
    0.1200
    0.1400
    0.1601
    0.1801
      ⋮
```

Total wheel displacements profile

```
figure
plot(t,R_acu(:,2),'b')
hold on
plot(t,L_acu(:,2),'r')
xlim ([0 Tf])
grid on
title('Wheels displacement')
xlabel ('Time [s]')
ylabel ('Displacement [m]')
legend('R','L')
```



Wheel incremental displacements

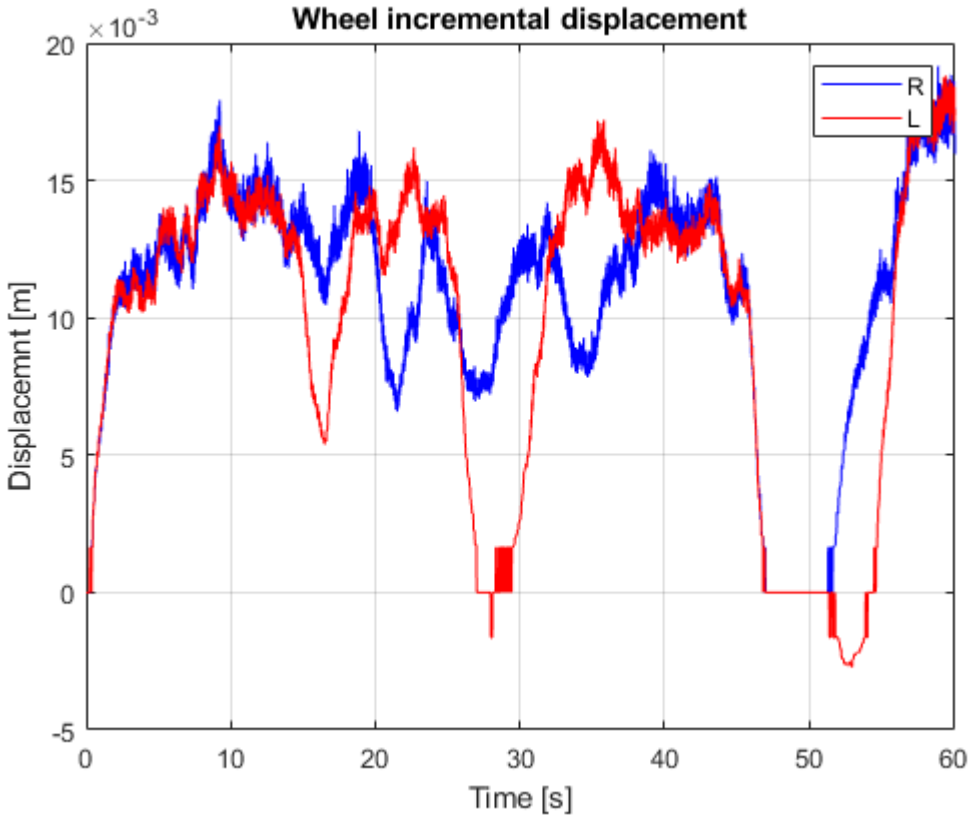
It tell us how much displacement did the wheel during a sample time.

$R_{\text{inc}} = R_{k+1} - R_k$

$L_{\text{inc}} = L_{k+1} - L_k$

Incremental displacements profile

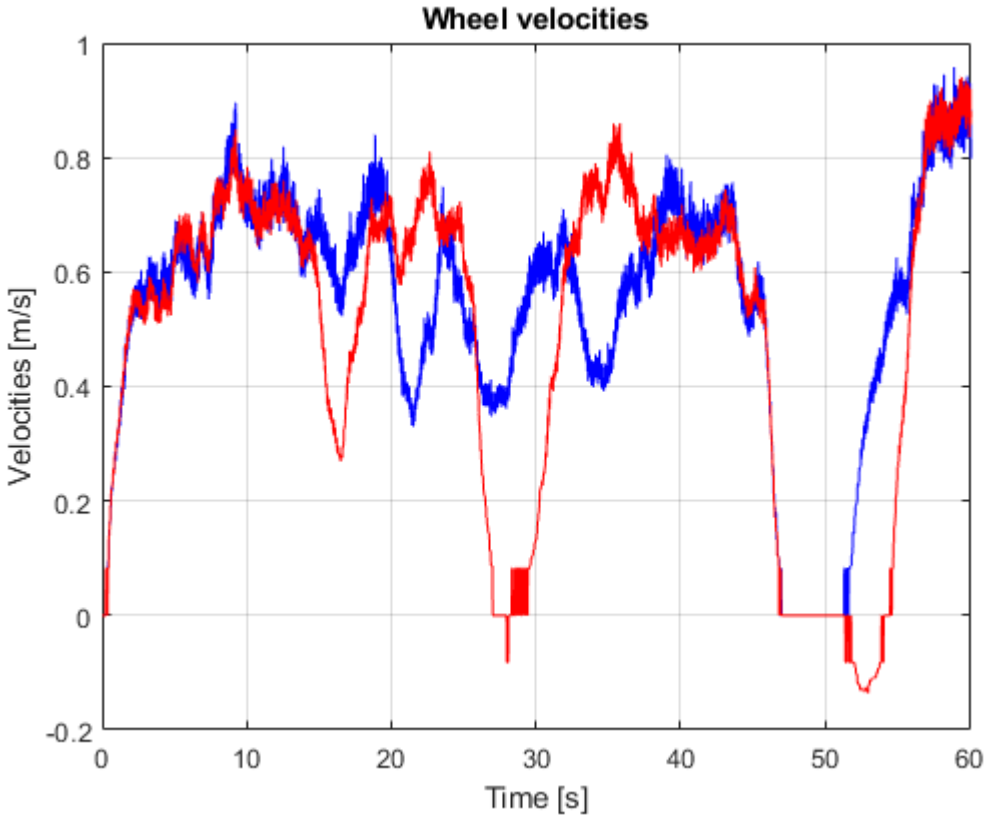
```
figure
plot(t,R_inc,'b') % We losted one sample with 'diff' command
hold on
plot(t,L_inc,'r') % We losted one sample with 'diff' command
hold on
xlim ([0 Tf])
grid on
title('Wheel incremental displacement')
xlabel ('Time [s]')
ylabel ('Displacemnt [m]')
legend('R','L')
```



Wheel velocities profile

$$\text{Velocity} = \frac{\Delta\text{displacemts}}{\Delta\text{time}} = \frac{\Delta e}{\Delta t} = \frac{\Delta R}{T_s} = \frac{R_{\text{inc}}}{T_s}$$

```
figure
plot(t,R_inc/Ts,'b')
hold on
plot(t,L_inc/Ts,'r')
xlim ([0 Tf])
grid on
title('Wheel velocities')
xlabel ('Time [s]')
ylabel ('Velocities [m/s]')
```



Equivalence of Encoder Data

Some time the microcontroller gives wheels increment displacement. To recover total wheel displacement

$$R_{\mathrm{acu}_k} = \int_0^{t_k} R_{\mathrm{inc}}(t)\mathrm{dt} \equiv \sum_i^k R_{\mathrm{inc}_i}$$

```
R_ac=cumsum(R_inc,1)
```

```
R_ac = 3004×1
     0
     0
     0
     0
     0
     0
     0
     0
     0
     0
     ⋮
```

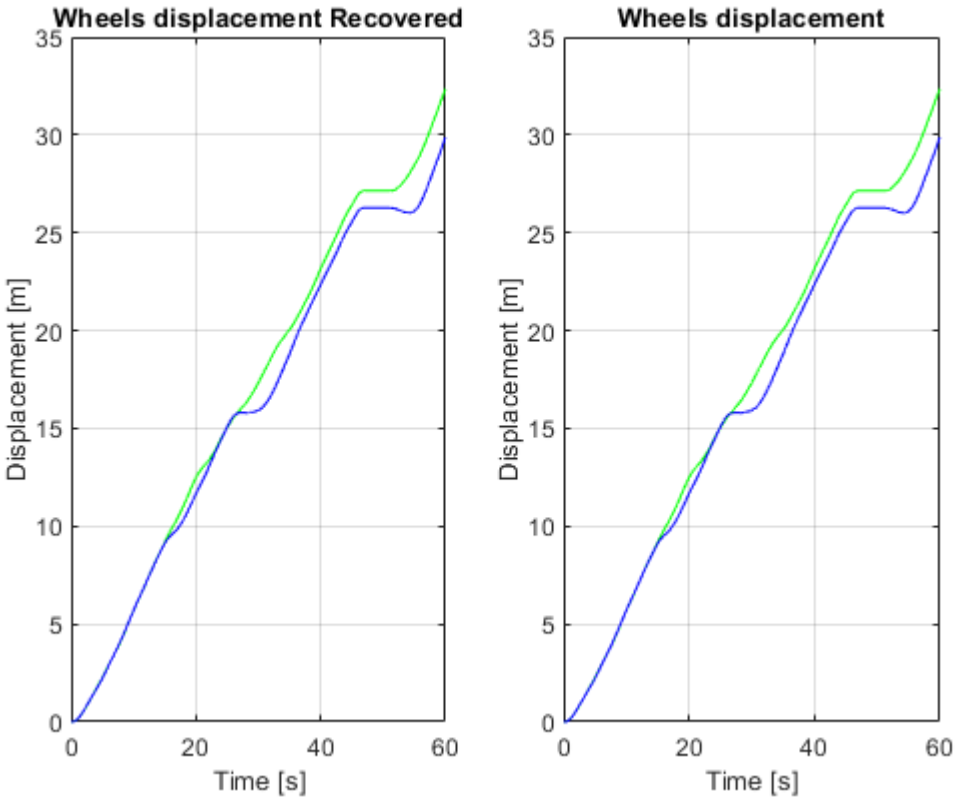
```
L_ac=cumsum(L_inc,1)
```

```
L_ac = 3004×1
     0
     0
     0
     0
     0
```

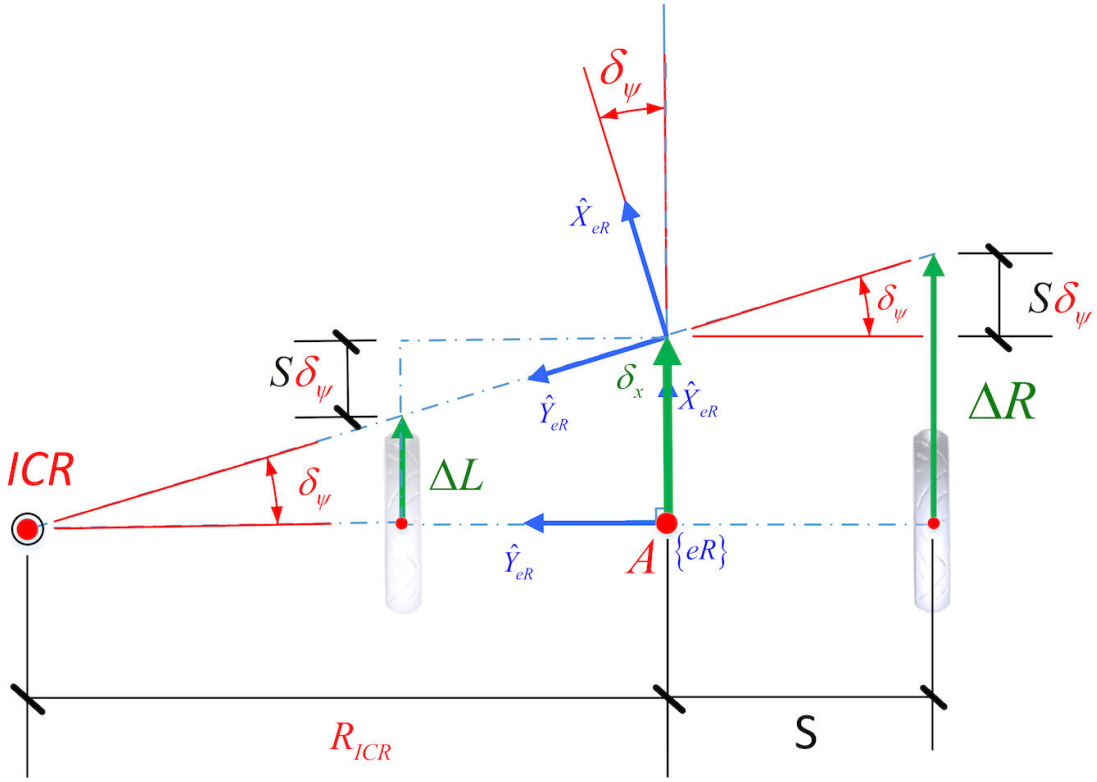
```
     0
     0
     0
     0
     0
     ⋮
```

Recovered wheel displacements profile

```
figure
subplot(1,2,1)
plot(t,R_ac,'g')
hold on
plot(t,L_ac,'b')
xlim ([0 Tf])
grid on
title('Wheels displacement Recovered')
xlabel ('Time [s]')
ylabel ('Displacement [m]')
subplot(1,2,2)
plot(t,R_acu(:,2),'g')
hold on
plot(t,L_acu(:,2),'b')
xlim ([0 Tf])
grid on
title('Wheels displacement')
xlabel ('Time [s]')
ylabel ('Displacement [m]')
```



Odometry



$$\delta_x = \frac{R_{inc} + L_{inc}}{2}$$

$$\delta_\Psi = \frac{R_{inc} - L_{inc}}{2S}$$

```
delta_d=(R_inc+L_inc)/2
```

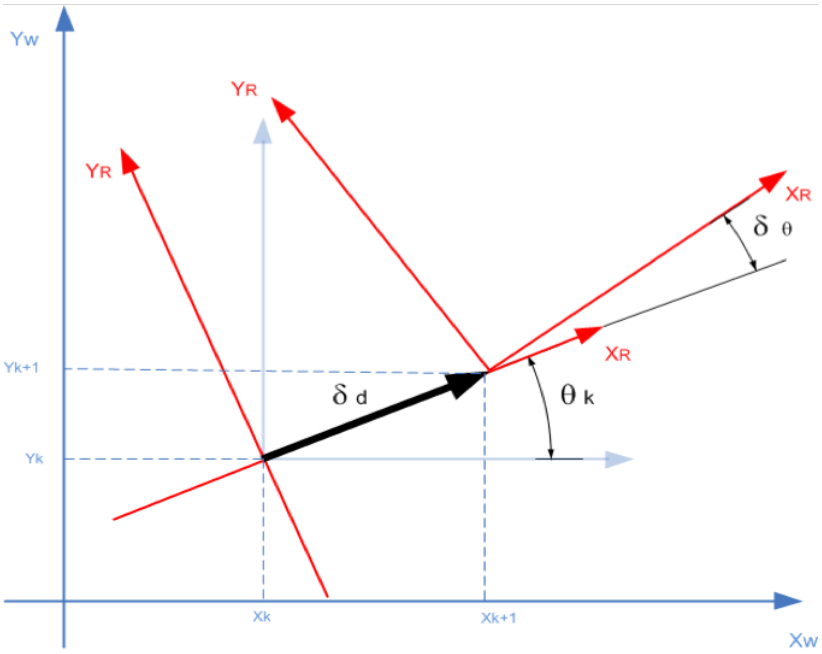
```
delta_d = 3004×1
     0
     0
     0
     0
     0
     0
     0
     0
     0
     0
     ⋮
```

```
delta_t=(R_inc-L_inc)/W
```

```
delta_t = 3004×1
     0
     0
     0
     0
     0
     0
```

```
     0
     0
     0
     0
     ⋮
```

Pose integration



Pose as a Frame description; $\xi_k = \begin{pmatrix} c\theta_k & -s\theta_k & x_k \\ s\theta_k & c\theta_k & y_k \\ 0 & 0 & 1 \end{pmatrix}$

Using post multiplication

Next pose; $\xi_{k+1} = \xi_k \tan sl_x(\delta_d) Rot_Z(\delta_\theta)$

```
Initial_pose=transl(8.65,17.2,0)*trotz(-pi/2)
```

```
Initial_pose = 4×4
         0    1.0000         0    8.6500
   -1.0000         0         0   17.2000
         0         0    1.0000         0
         0         0         0    1.0000
```

```
Pose(:,:,1)=Initial_pose;
 for i=1:length(t)-1
    Pose(:,:,i+1)=Pose(:,:,i)*transl(delta_d(i),0,0)*trotz(delta_t(i));
    %Pose(:,:,i+1)=Pose(:,:,i)*trotz(delta_t(i))*transl(delta_d(i),0,0);
    Position(:,i+1)=transl(Pose(:,:,i));
    Orientation(:,i+1)=tr2rpy(Pose(:,:,i));
```

```
  end
```

or using

$$\xi_{k+1} = \begin{pmatrix} p_{k+1} \\ \theta_{k+1} \end{pmatrix} = \begin{pmatrix} x_k + \delta_d c\theta_k \\ y_k + \delta_d s\theta_k \\ \theta_k + \delta_\theta \end{pmatrix}$$

```
  Initial_position=transl(Initial_pose)
```

```
Initial_position = 3×1
    8.6500
   17.2000
         0
```

```
Initial_orientation=-pi/2
```

```
Initial_orientation = -1.5708
```

```
x(1)=Initial_position(1)+0.05 % for comparing reasons we offset x by 5cm
```

```
x = 8.7000
```

```
y(1)=Initial_position(2)
```

```
y = 17.2000
```

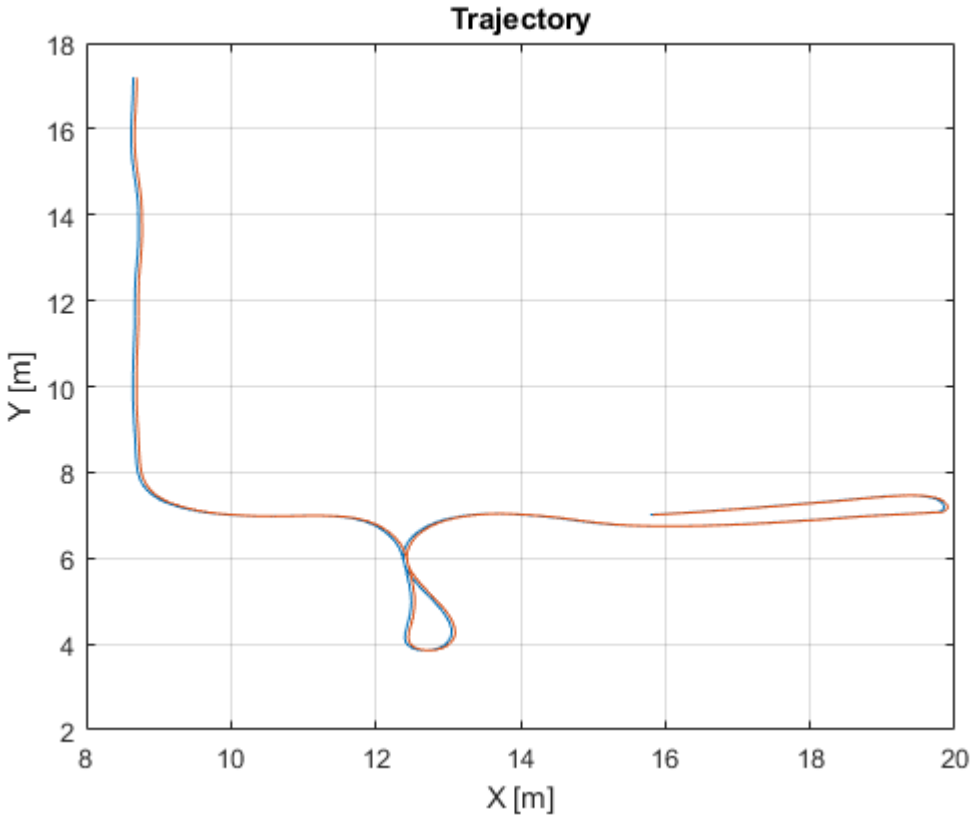
```
o(1)=Initial_orientation
```

```
o = -1.5708
```

```
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)=o(i)+delta_t(i);
end
```

Displaying trajectory

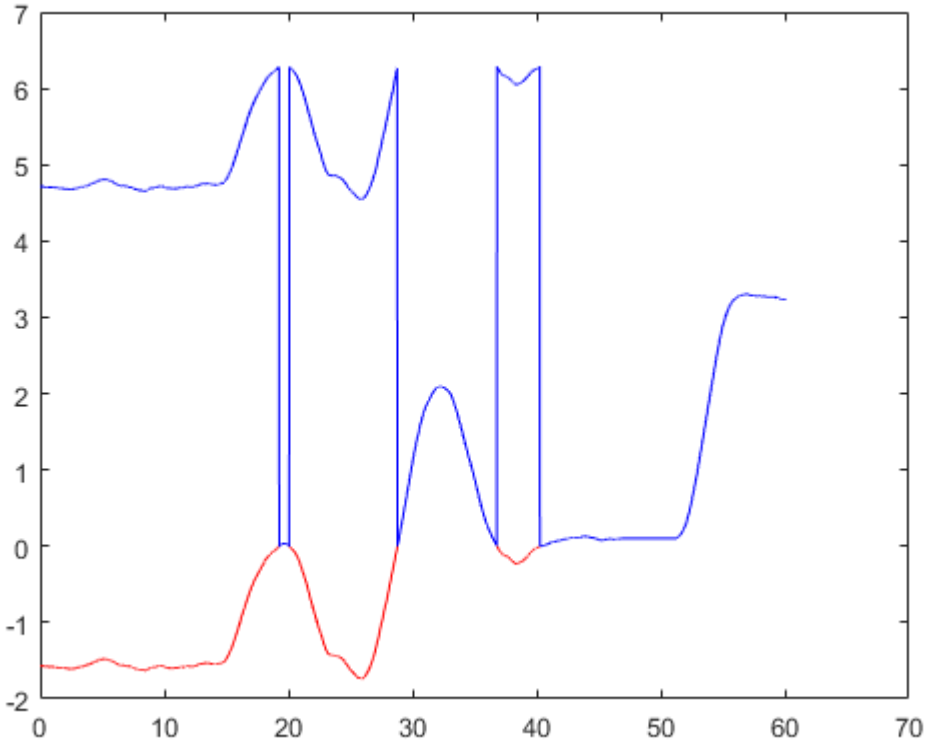
```
figure
plot(Position(1,2:end),Position(2,2:end))
grid on
hold on
title('Trajectory')
xlabel ('X [m]')
ylabel ('Y [m]')
plot(x,y)
```



Understanding Orientation

Think about $\sin\left(-\frac{\pi}{2}\right) = \sin\left(\frac{3}{2}\pi\right) = \sin\left(2\pi + \frac{3}{2}\pi\right)$

```
figure
plot(t,o,'r')
hold on
plot(t,mod(o,2*pi),'b')
```



Plotting the enviroment and trajectory

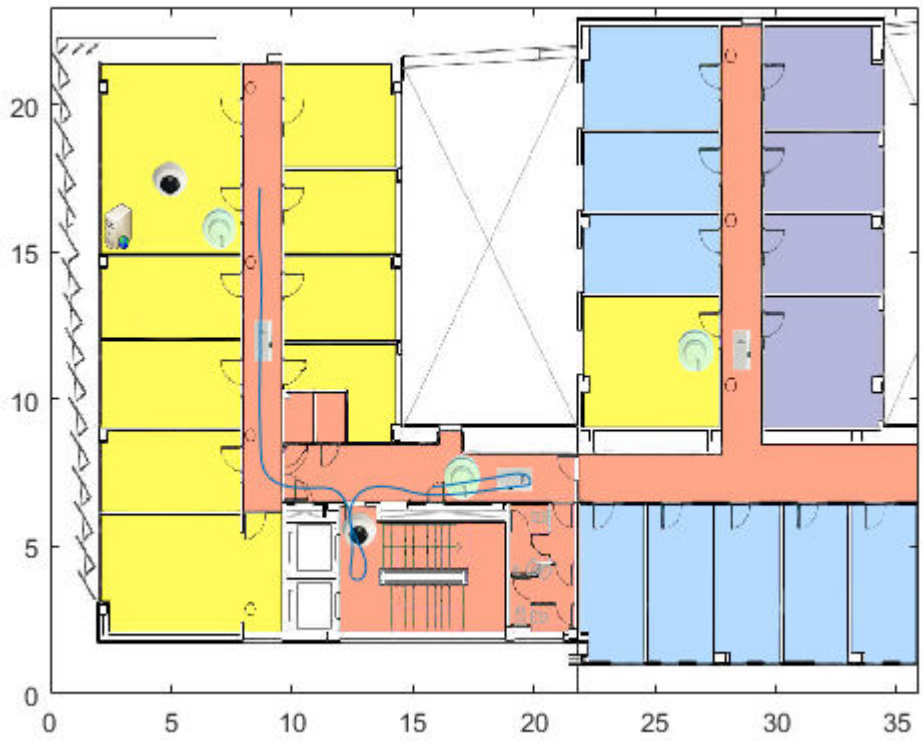
```
figure1=figure
```

```
figure1 =
  Figure (7) with properties:

      Number: 7
        Name: ''
       Color: [0.9400 0.9400 0.9400]
    Position: [680 558 560 420]
       Units: 'pixels'

  Show all properties
```

```
I=imread('Enviroment.png');
x_ima=[0 35.9];
y_ima=[23.31 0];
image(I,'XData',x_ima,'YData',y_ima);
axis xy
hold on
plot(Position(1,2:end),Position(2,2:end))
```



Uncertanty: Adding noise

$$\delta_d = \frac{R+L}{2} + \nu_d$$

$$\delta_\theta = \frac{R-L}{2S} + \nu_\theta$$

Noise in the odometry displacement

```
delta_d_n=((R_inc+L_inc)/2)+randn((length(t)),1)*0.005
```

```
delta_d_n = 3004×1
    0.0027
    0.0092
   -0.0113
    0.0043
    0.0016
   -0.0065
   -0.0022
    0.0017
    0.0179
    0.0138
      ⋮
```

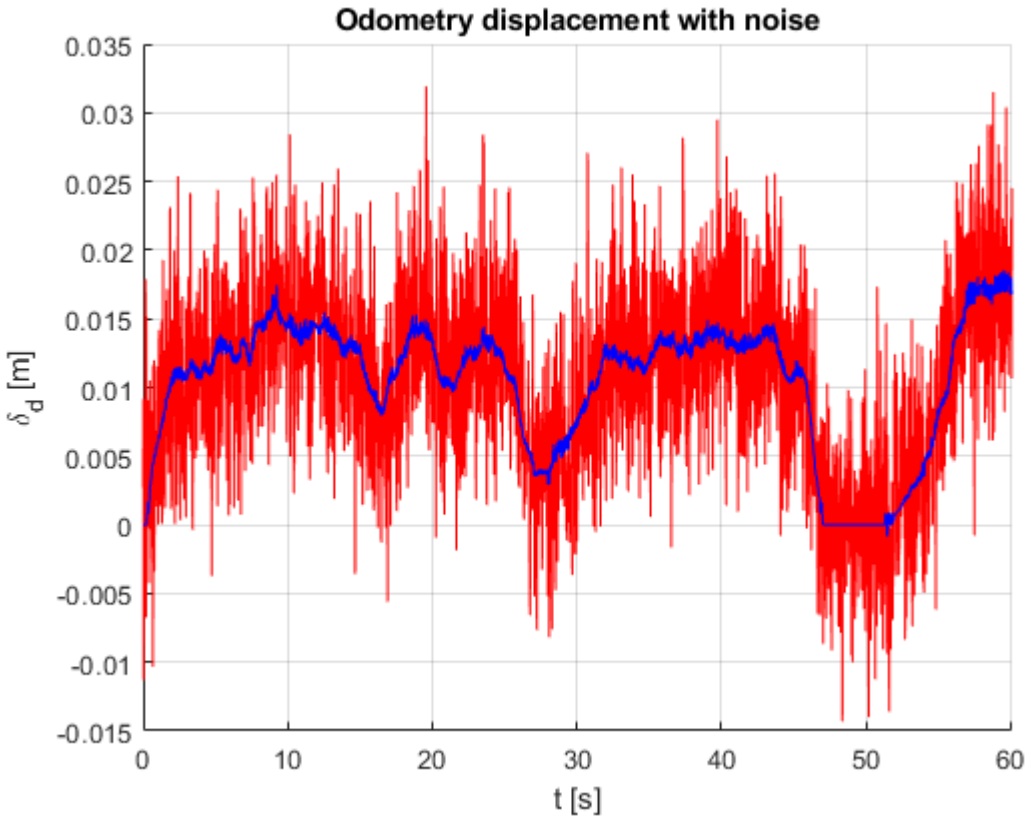
Noise in the odometry change of orientation

```
delta_t_n=((R_inc-L_inc)/W)+randn((length(t)),1)*0.005
```

```
delta_t_n = 3004×1
   -0.0031
   -0.0035
   -0.0071
   -0.0005
   -0.0005
   -0.0016
   -0.0042
   -0.0083
    0.0151
    0.0075
      ⋮
```

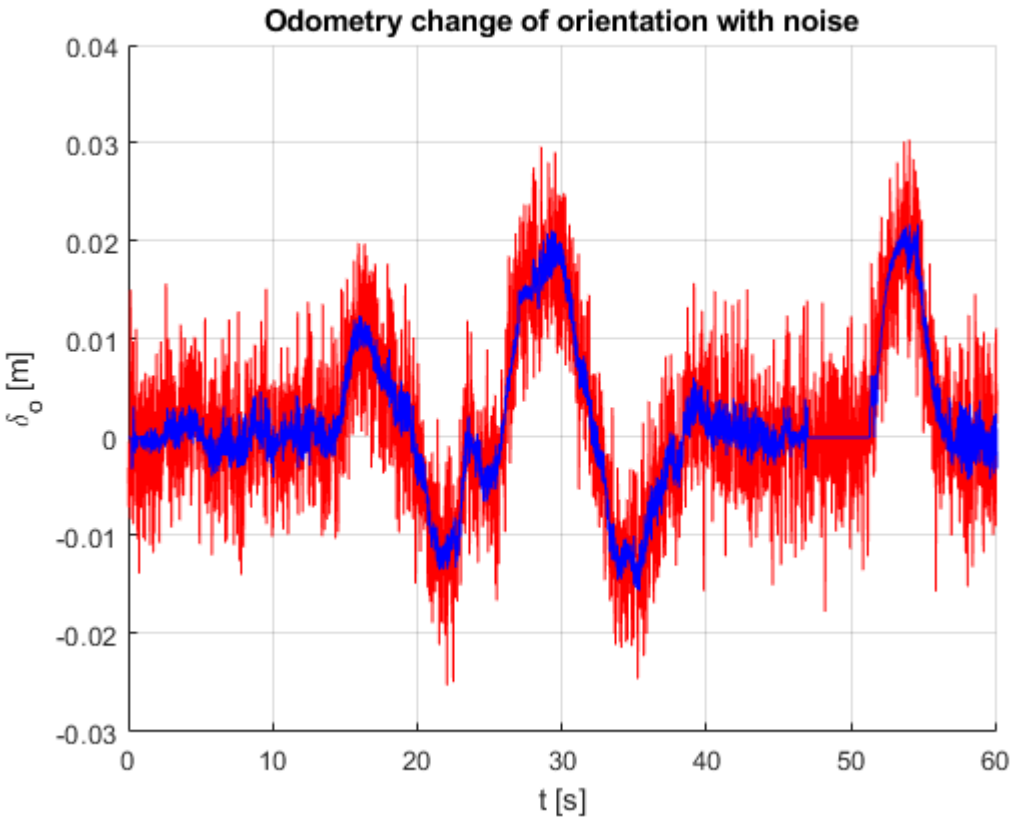
Displacement noise visualization

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



Orientation noise visualization

```
figure
hold on
plot(t,delta_t_n,'r')
xlim ([0 Tf])
grid on
title('Odometry change of orientation with noise')
xlabel ('t [s]')
ylabel ('\delta_o [m]')
plot(t,delta_t,'b')
```



Pose integration with noise

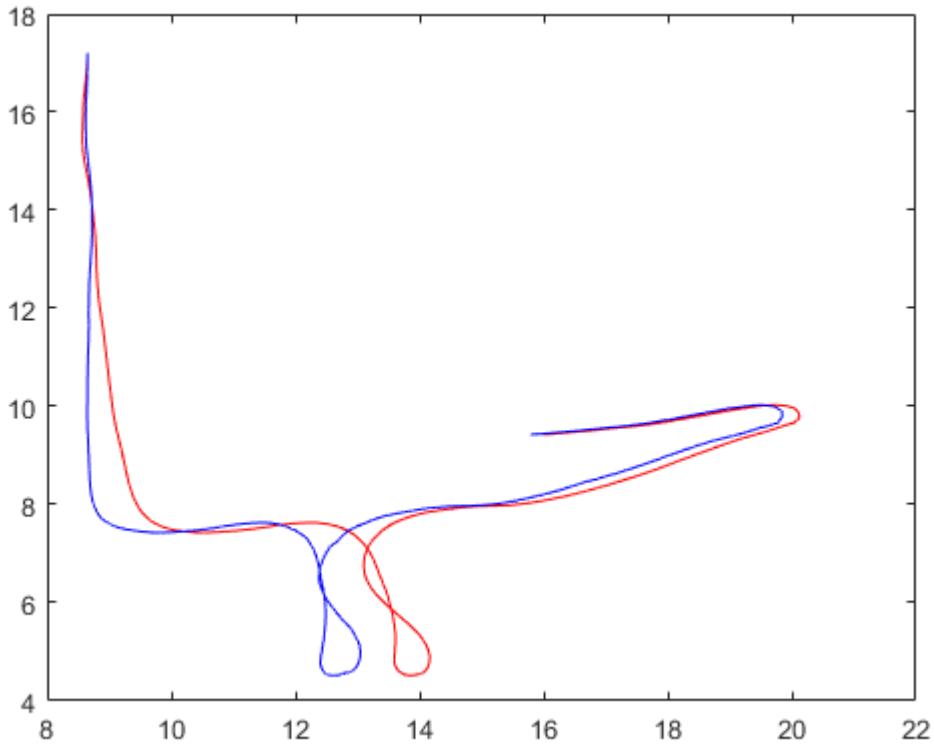
```
Initial_pose=transl(8.65,17.2,0)*trotz(-pi/2)
```

```
Initial_pose = 4×4
         0    1.0000         0    8.6500
   -1.0000         0         0   17.2000
         0         0    1.0000         0
         0         0         0    1.0000
```

```
Pose_n(:,:,1)=Initial_pose;
 for i=1:length(t)-1
    Pose_n(:,:,i+1)=Pose_n(:,:,i)*transl(delta_d_n(i),0,0)*trotz(delta_t_n(i));
    Position_n(:,i+1)=transl(Pose_n(:,:,i));
    Orientation_n(:,i+1)=tr2rpy(Pose_n(:,:,i));
 end
```

Comparing trajectories

```
figure
plot(Position_n(1,2:end),Position_n(2,2:end),'r')
hold on
plot(Position(1,2:end),Position_n(2,2:end),'b')
```



Ellipse error

It is of interest to launch many time the dices (our trajectory with noise) and check for the last position and orientation

```
Initial_pose=transl(8.65,17.2,0)*trotz(-pi/2)
```

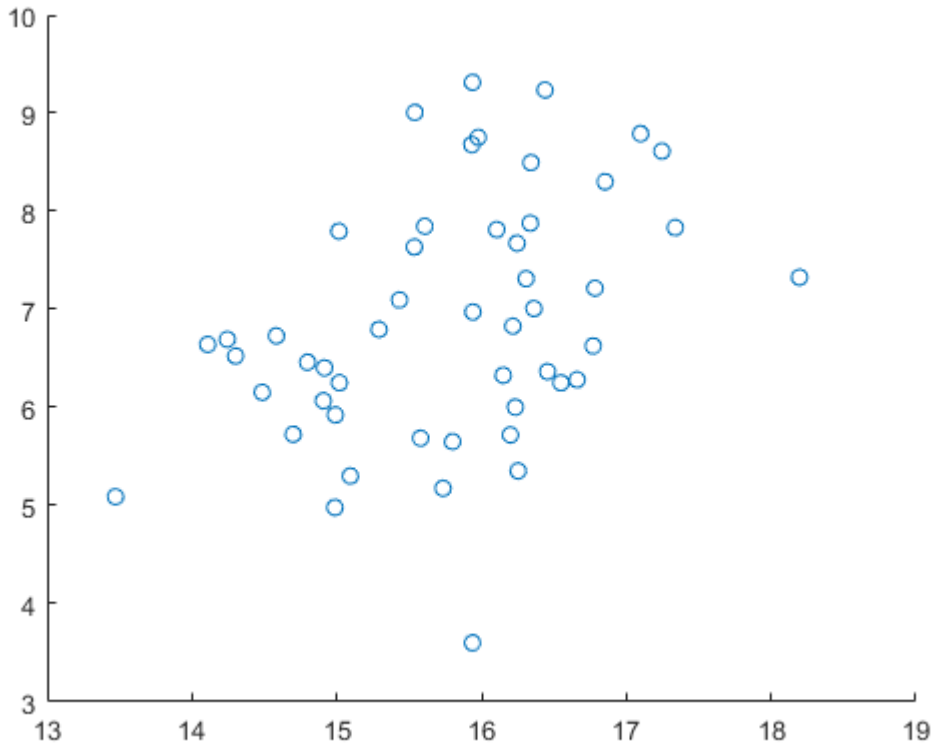
```
Initial_pose = 4×4
         0    1.0000         0    8.6500
   -1.0000         0         0   17.2000
         0         0    1.0000         0
         0         0         0    1.0000
```

```
Pose_n(:,:,1)=Initial_pose;
for j=1:50
delta_d_n=((R_inc+L_inc)/2)+randn((length(t)),1)*0.005; %Dices again
delta_t_n=((R_inc-L_inc)/W)+randn((length(t)),1)*0.005;
 for i=1:length(t)
    Pose_n(:,:,i+1)=Pose_n(:,:,i)*transl(delta_d_n(i),0,0)*trotz(delta_t_n(i));
    Position_n(:,i+1)=transl(Pose_n(:,:,i));
    Orientation_n(:,i+1)=tr2rpy(Pose_n(:,:,i));
```

```
 end
 Positions_n(:,j)=Position_n(:,end);
 Orientations_n(:,j)=Orientation_n(:,end);
end
```

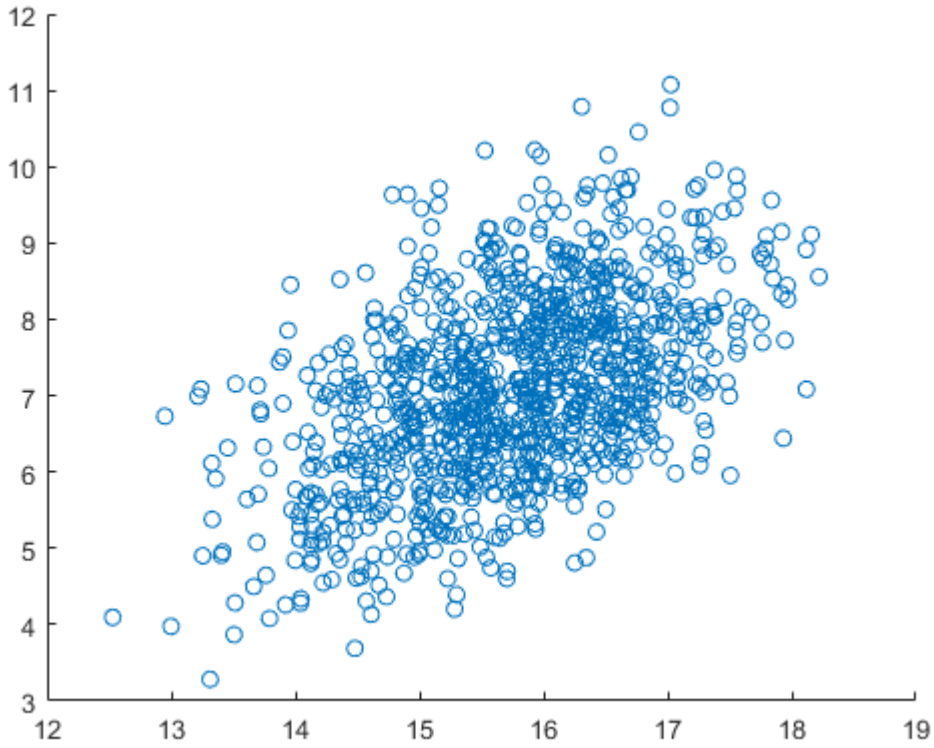
Visualizing the experimental ellipse error of final position

```
figure
scatter(Positions_n(1,:),Positions_n(2,:))
```



This image is with 1000 launch the dices

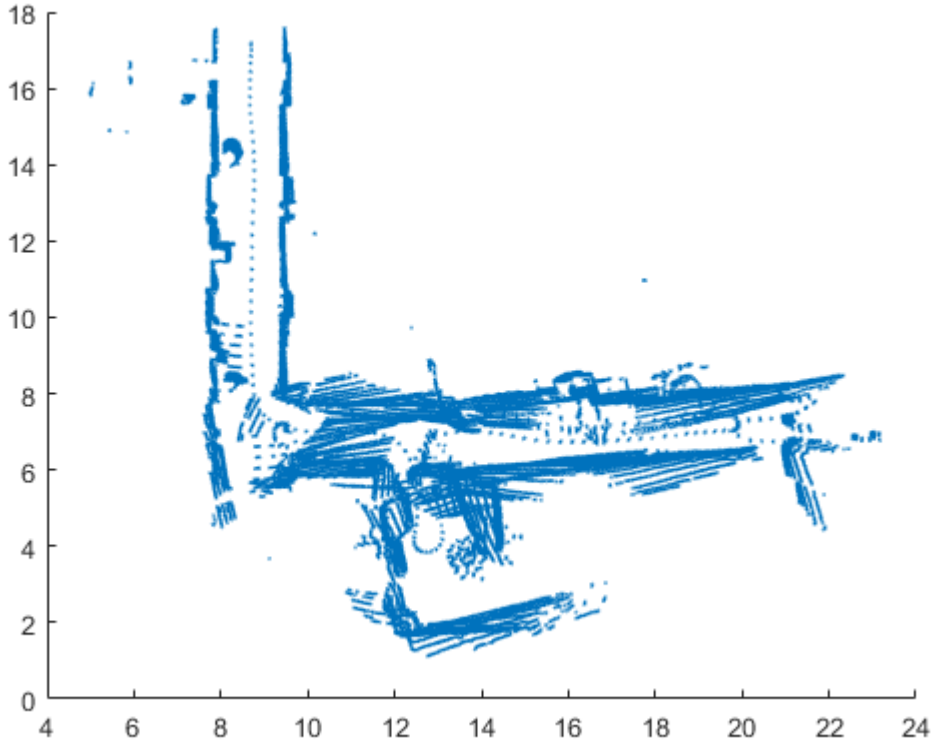
```
load('Dice_launch_1000.mat')
figure
scatter(Positions_1000(1,:),Positions_1000(2,:))
```



Mapping

```
count = 1;
m = size(polar_laser_data);
for i=1:m(1)
    for j=1:(m(2)-1)
        if polar_laser_data(i, j)/1000 > 0
            alpha = (j-1) * 0.3515 * pi/180;
            if alpha <= 240/2
                alpha = o(20*i) + alpha - 122*pi/180;
            else
                alpha = o(20*i) - alpha - 122*pi/180;
            end
            x2(count) = x(20*i) + polar_laser_data(i, j)/1000 * cos(alpha);
            y2(count) = y(20*i) + polar_laser_data(i, j)/1000 * sin(alpha);
            count = count + 1;
        end
    end
end

figure
scatter(x2, y2, 0.5, '.')
```


18
16
14
12
10
8
6
4
2
0
4
6
8
10
12
14
16
18
20
22
24