Actividad 7.1 (Waypoints)

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1. Resumen

Este reporte unifica seis simulaciones de seguimiento de waypoints usando Pure Pursuit sobre un robot diferencial. Primero presentamos tres trayectorias fijas y luego tres trayectorias con forma (perro,flor y cereza). En cada caso, Pure Pursuit calcula en tiempo real las velocidades lineal y angular y Euler explícito actualiza la pose del robot.

2. Parámetros de simulacion

Parámetro	Descripción	Efecto de variarlo	Rango típico
sampleTime	Paso de integración de Euler (resolución temporal de la simulación)	- Muy grande → salto excesivo, pérdida de trayectoria- Muy pequeño → alta carga de cómputo	0.01 – 0.1 s
tVec	Vector de tiempo total de la simulación	- Corto → robot no alcanza todos los waypoints- Largo → simulación ineficiente	Según longitud y velocidad deseada
initPose	Pose inicial [x;y;θ] [x;y;\theta]	- Mal orientado → giros innecesarios- Bien orientado → arranque suave	Definido visualmente según forma

3.Parametros de Pure Pursuit

Parámetro	Descripción	Efecto de variarlo	Rango típico
LookaheadDistance	Distancia a un punto adelantado en la ruta	- Muy grande → “corta” vértices, pierde precisión- Muy pequeña → zigzags, oscilaciones	0.1 – 1.0 m
DesiredLinearVelocity	Velocidad lineal constante deseada	- Muy alta → deriva en curvas- Muy baja → recorrido lento	0.3 – 1.0 m/s
MaxAngularVelocity	Límite de velocidad angular	- Muy bajo → no gira a tiempo en curvas cerradas- Muy alto → posibles oscilaciones	1.0 – 3.0 rad/s
goalRadius	Radio de aceptación para cambiar al siguiente waypoint	- Muy pequeño → oscila alrededor del punto- Muy grande → salta rápido al siguiente waypoint	0.1 – 0.5 m
Densidad de waypoints	Número y separación de puntos de referencia	- Pocos & separados → rutas “cortadas”- Muchos & juntos →	Manual/según forma

		suavidad pero mayor cálculo de controller	

Parte 1

```
clear; close all; clc


% Defino el robot diferencial
R  = 0.05;           % Radio de rueda [m]
L  = 0.18;           % Separación entre ruedas [m]
dd = DifferentialDrive(R, L);

% Parámetros de simulación comunes
sampleTime = 0.1;
tVec       = 0:sampleTime:160;


% ---- Trayectoria 1
initPose    = [4; 4; 0];
pose         = zeros(3, numel(tVec));
pose(:,1)    = initPose;
waypoints    = [
   -10,  8;
     8, -1;
    -7, -6;
     0,  5;
    -3,   0;
     2, -5;
     0,   0
];

figure(1); clf
viz1 = Visualizer2D;              % Visualizo robot y waypoints
viz1.hasWaypoints = true;

controller = controllerPurePursuit;    % Configuro Pure Pursuit
controller.LookaheadDistance    = 1.0;
controller.DesiredLinearVelocity= 0.6;
controller.MaxAngularVelocity   = 1.2;

r = rateControl(1/sampleTime);
currentIdx = 1;
goalRadius = 0.3;

for idx = 2:numel(tVec)
    if currentIdx > size(waypoints,1), break; end
```

```
    % Actualizo waypoint objetivo
    controller.Waypoints = [pose(1:2,idx-1)' ; waypoints(currentIdx,:)];
    [vRef,wRef]          = controller(pose(:,idx-1));

    % Cinemática diferencial
    [wL,wR]              = inverseKinematics(dd, vRef, wRef);
    [v, w]               = forwardKinematics(dd, wL, wR);
    vel                  = bodyToWorld([v;0;w], pose(:,idx-1));

    % Euler explícito
    pose(:,idx) = pose(:,idx-1) + vel * sampleTime;

    % Cambio de waypoint
    if norm(pose(1:2,idx) - waypoints(currentIdx,:)') < goalRadius
        currentIdx = currentIdx + 1;
    end

    viz1(pose(:,idx), waypoints);  % Dibujo
    waitfor(r);
end
```

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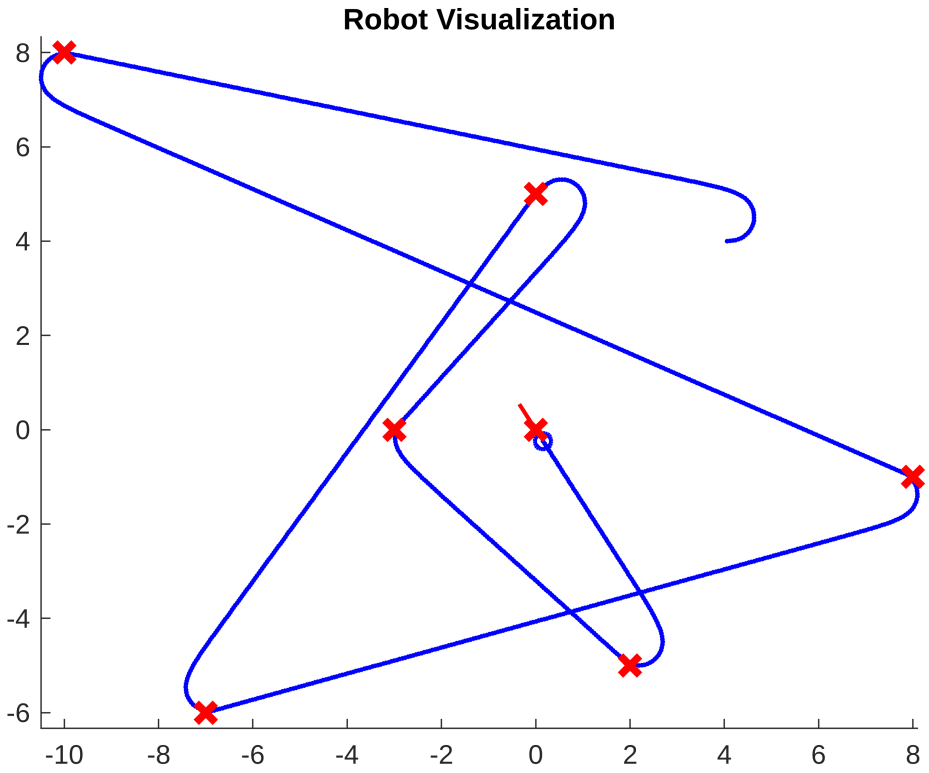


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% ---- Trayectoria 2
initPose    = [2; 5; 0];
```

```
pose         = zeros(3, numel(tVec));
pose(:,1)    = initPose;
waypoints    = [
    -5,  3;
    -5, -2;
     2, -5;
     5,  2;
    -3,  2;
    -4, -4;
     4, -3
];

figure(2); clf
viz2 = Visualizer2D; viz2.hasWaypoints = true;
controller.Waypoints = waypoints;
currentIdx = 1;

for idx = 2:numel(tVec)
    if currentIdx > size(waypoints,1), break; end

    controller.Waypoints = [pose(1:2,idx-1)' ; waypoints(currentIdx,:)];
    [vRef,wRef]         = controller(pose(:,idx-1));
    [wL,wR]             = inverseKinematics(dd, vRef, wRef);
    [v, w]              = forwardKinematics(dd, wL, wR);

    vel                 = bodyToWorld([v;0;w], pose(:,idx-1));
    pose(:,idx)         = pose(:,idx-1) + vel * sampleTime;

    if norm(pose(1:2,idx) - waypoints(currentIdx,:)') < goalRadius
        currentIdx = currentIdx + 1;
    end

    viz2(pose(:,idx), waypoints);
    waitfor(r);
end
```

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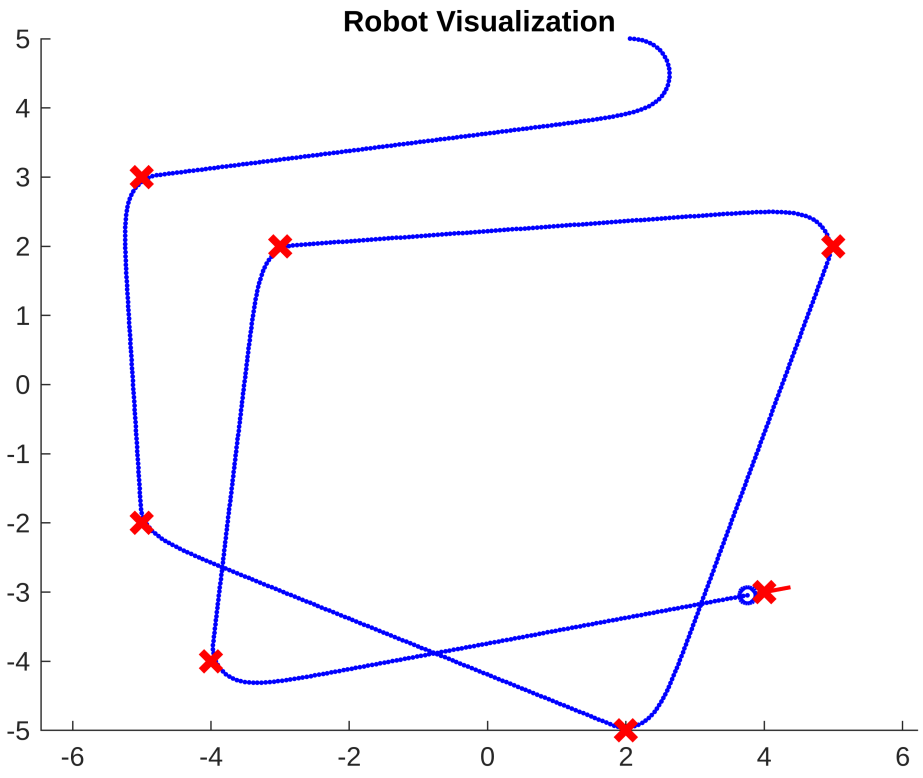


```
% ---- Trayectoria 3
initPose    = [-3; 4; 0];
pose         = zeros(3, numel(tVec));
pose(:,1)    = initPose;
waypoints    = [
     3,  3;
     1, -3;
    -1, -1;
     1,  4;
    -3, -4;
     2, -1
];

figure(3); clf
viz3 = Visualizer2D; viz3.hasWaypoints = true;
controller.Waypoints = waypoints;
currentIdx = 1;

for idx = 2:numel(tVec)
    if currentIdx > size(waypoints,1), break; end

    controller.Waypoints = [pose(1:2,idx-1)' ; waypoints(currentIdx,:)];
    [vRef,wRef]         = controller(pose(:,idx-1));
    [wL,wR]             = inverseKinematics(dd, vRef, wRef);
    [v, w]              = forwardKinematics(dd, wL, wR);
```

```
    vel                 = bodyToWorld([v;0;w], pose(:,idx-1));
    pose(:,idx)         = pose(:,idx-1) + vel * sampleTime;

    if norm(pose(1:2,idx) - waypoints(currentIdx,:)') < goalRadius
        currentIdx = currentIdx + 1;
    end

    viz3(pose(:,idx), waypoints);
    waitfor(r);
end
```

```
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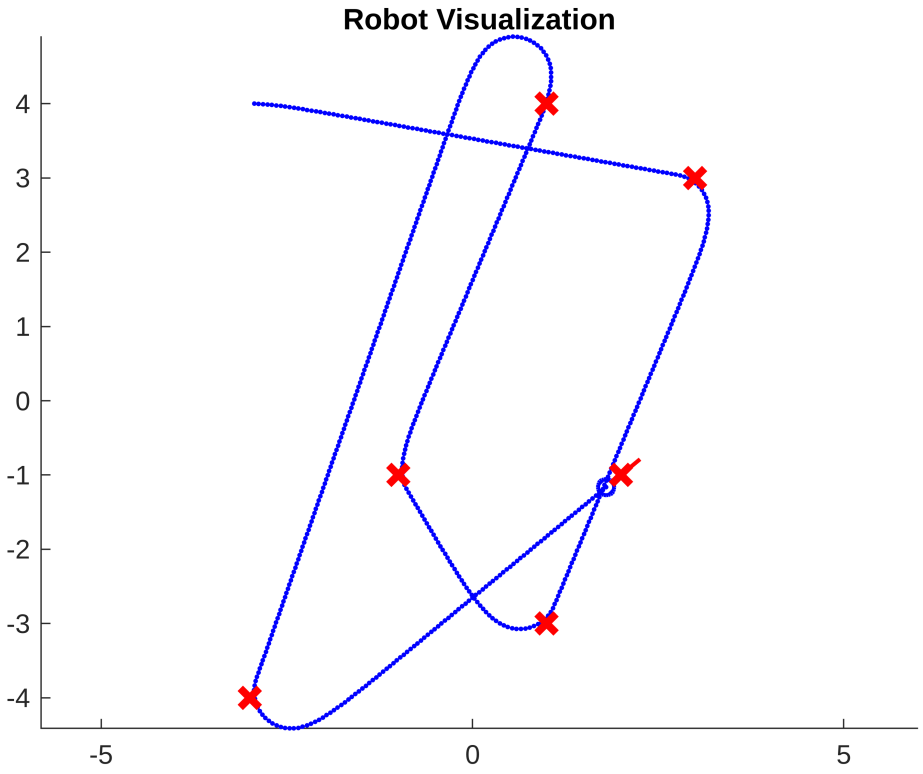

Parte 2

```
% ---- Perro
R1  = 0.1; L1 = 0.5;
dd1 = DifferentialDrive(R1,L1);

sampleTime1 = 0.08;
tVec1       = 0:sampleTime1:82;

initPose1    = [-5.49; 2.36; 0];
pose1        = zeros(3, numel(tVec1));
```

```
pose1(:,1)   = initPose1;

waypoints1 = [
   -5.49,  2.36;  -4.33,  2.34;  -3.17,  2.32;
   -3.20,  2.84;  -3.23,  3.36;  -2.12,  3.81;
   -1.01,  4.26;  -1.00,  4.89;  -0.99,  5.52;
   -0.47,  5.04;   0.05,  4.56;   0.56,  4.54;
    1.07,  4.52;   1.09,  5.02;   1.11,  5.52;
    2.20,  3.40;   3.29,  1.28;   3.84,  0.71;
    4.39,  0.14;   4.95, -0.41;   5.51, -0.96;
    6.07, -1.01;   6.63, -1.06;   3.87, -4.32;
    1.11, -7.58;   0.61, -6.54;   0.11, -5.50;
    0.14, -4.34;   0.17, -3.18;   0.15, -2.68;
    0.13, -2.18;  -0.44, -1.59;  -1.00, -1.00;
   -2.60, -0.95;  -4.19, -0.90;  -3.76, -0.42;
   -3.33,  0.06;  -2.73,  0.07;  -2.13,  0.08;
   -3.79,  0.67;  -5.45,  1.26;  -5.47,  1.81;
   -5.49,  2.36
];

figure(4); clf
viz4 = Visualizer2D; viz4.hasWaypoints = true;

controller1 = controllerPurePursuit;
controller1.Waypoints             = waypoints1;
controller1.LookaheadDistance     = 0.09;
controller1.DesiredLinearVelocity = 0.75;
controller1.MaxAngularVelocity    = 2.13;

r1 = rateControl(1/sampleTime1);

for k = 2:numel(tVec1)
    [vRef,wRef] = controller1(pose1(:,k-1));
    [wL,wR]     = inverseKinematics(dd1, vRef, wRef);
    [v, w]      = forwardKinematics(dd1, wL, wR);
    vel         = bodyToWorld([v;0;w], pose1(:,k-1));
    pose1(:,k)  = pose1(:,k-1) + vel * sampleTime1;
    viz4(pose1(:,k), waypoints1);
    waitfor(r1);
end
```

```
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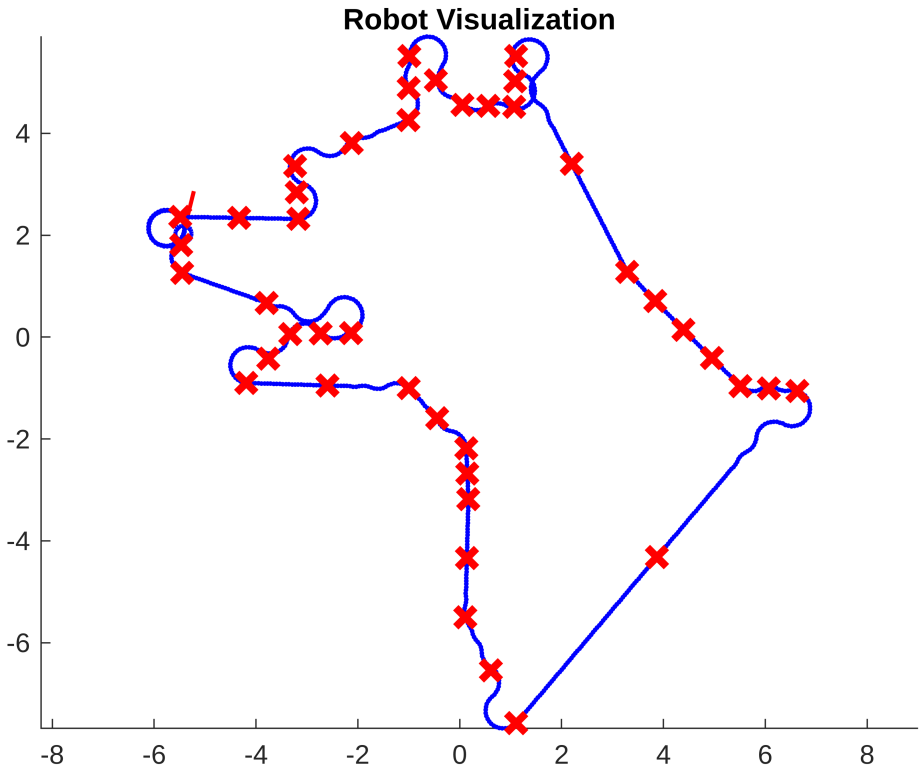


```
% ---- Flor  ----
R2  = 0.1; L2 = 0.5;
dd2 = DifferentialDrive(R2,L2);

sampleTime2 = 0.2;
tVec2       = 0:sampleTime2:45;

initPose2    = [0.06; -1.36; pi/4];
pose2        = zeros(3, numel(tVec2));
pose2(:,1)   = initPose2;

waypoints2 = [
    0.06, -1.36;  0.73, -0.71;  1.41, -0.69;
    0.75, -1.38; -0.63, -1.37; -1.25, -0.71;
   -0.63, -0.69;  0.06, -1.36;  0.06, -0.08;
   -0.63, -0.69; -0.61, -0.01; -1.25, -0.02;
   -0.63,  0.65; -1.27,  1.32; -0.62,  1.34;
   -0.62,  2.01;  0.07,  1.34;  0.73,  2.01;
    0.74,  1.33;  1.40,  1.34;  0.76,  0.65;
    1.42, -0.01;  0.75, -0.02;  0.73, -0.68;
    0.07, -0.06;  0.06,  0.31; -0.27,  0.32;
   -0.26,  0.99;  0.40,  0.99;  0.40,  0.31;
    0.06,  0.31
];
```

```
figure(5); clf
viz5 = Visualizer2D; viz5.hasWaypoints = true;

controller2 = controllerPurePursuit;
controller2.Waypoints               = waypoints2;
controller2.LookaheadDistance       = 0.35;
controller2.DesiredLinearVelocity   = 0.5;
controller2.MaxAngularVelocity      = 3;

r2 = rateControl(1/sampleTime2);

for k = 2:numel(tVec2)
    [vRef,wRef] = controller2(pose2(:,k-1));
    [wL,wR]     = inverseKinematics(dd2, vRef, wRef);
    [v, w]      = forwardKinematics(dd2, wL, wR);
    vel         = bodyToWorld([v;0;w], pose2(:,k-1));
    pose2(:,k)  = pose2(:,k-1) + vel * sampleTime2;
    viz5(pose2(:,k), waypoints2);
    waitfor(r2);
end
```

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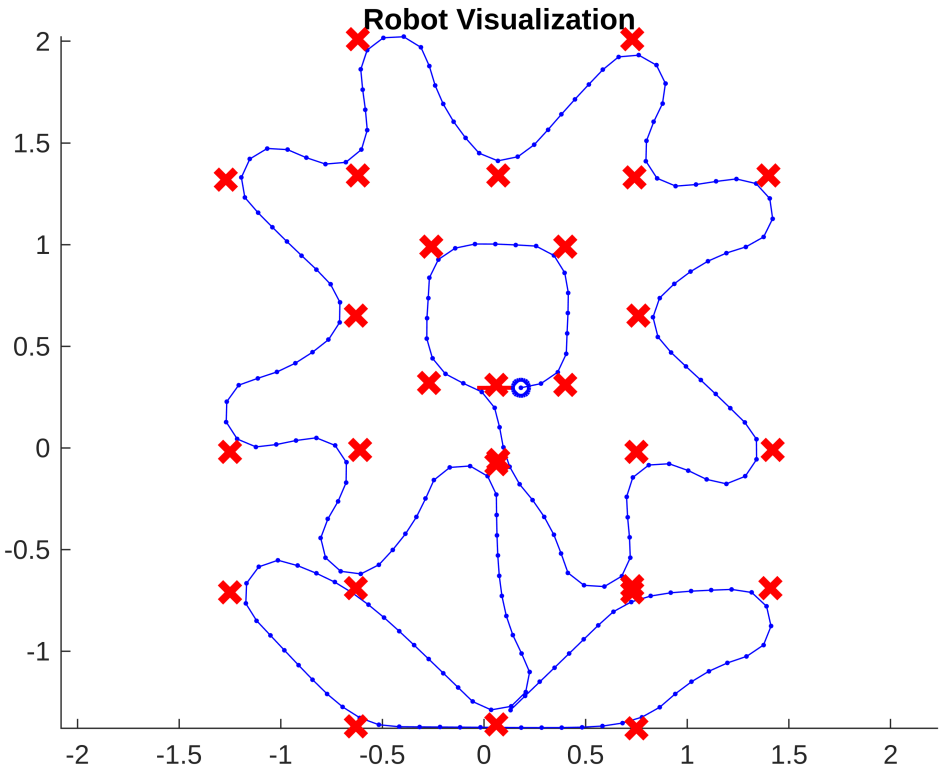


```
% ---- Cereza ----
R3  = 0.05; L3 = 0.18;
```

```
dd3 = DifferentialDrive(R3,L3);

sampleTime3 = 0.04;
tVec3       = 0:sampleTime3:300;

initPose3    = [7.8; 6.2; 0];
pose3        = zeros(3, numel(tVec3));
pose3(:,1)   = initPose3;

waypoints3 = [
    9,5;  9,3;  7,1;  5,1;  3,3;  3,5;  5,7;
    7,7; 7.8,6.2; 10,9; 8,11; 6,11; 4,9; 10,9;
   7.8,6.2; 7,5; 6,6; 7,5; 8,5
];

figure(6); clf
viz6 = Visualizer2D; viz6.hasWaypoints = true;

controller3 = controllerPurePursuit;
controller3.LookaheadDistance     = 0.2;
controller3.DesiredLinearVelocity = 0.35;
controller3.MaxAngularVelocity    = 1.6;

r3 = rateControl(1/sampleTime3);
currentIdx3 = 1;
goalRadius3 = 0.2;

for k = 2:numel(tVec3)
    if currentIdx3 > size(waypoints3,1), break; end

    controller3.Waypoints = [pose3(1:2,k-1)' ; waypoints3(currentIdx3,:)];
    [vRef,wRef]          = controller3(pose3(:,k-1));
    [wL,wR]              = inverseKinematics(dd3, vRef, wRef);
    [v, w]               = forwardKinematics(dd3, wL, wR);
    vel                  = bodyToWorld([v;0;w], pose3(:,k-1));
    pose3(:,k)           = pose3(:,k-1) + vel * sampleTime3;

    if norm(pose3(1:2,k) - waypoints3(currentIdx3,:)') < goalRadius3
        currentIdx3 = currentIdx3 + 1;
    end

    viz6(pose3(:,k), waypoints3);
    waitfor(r3);
end
```

```
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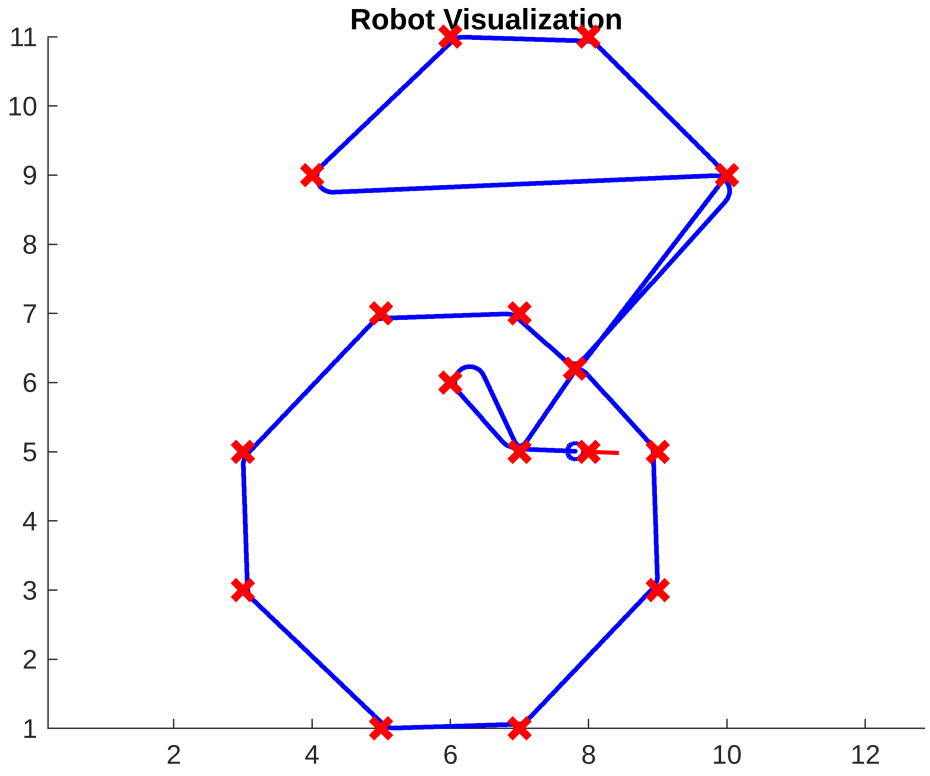
Robot Visualization
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