Evaluación: Localización de un robot diferencial

Paola Rojas Domínguez A01737136

Inicialización

Se inicia limpiando la consola y la memoria para evitar conflictos de datos anteriores.

```
clear all
close all
clc
```

Ejercicio 1

Tiempo

Se definen los parámetros temporales del experimento: tiempo de intregración por paso (`ts`), y el numero de pasos (N)

```
ts = 1;
N = 12;
```

Pose inicial

Se define la coordenada y orientación inicial del robot

```
x = -1;
y = -5;
theta = deg2rad(0);
```

Pasos

Se establece el historial de pasos descrito en el ejercicio

```
pasos = [
    1.0,   0.0;
    0.0,  pi/3;
    1.0,   0.0;
    0.0,  pi/3;
    1.0,   0.0;
    0.0,  pi/3;
    1.0,   0.0;
    0.0,  pi/3;
    1.0,   0.0;
    0.0,  pi/3;
    1.0,   0.0;
    0.0,  pi/3
];
```

Bucle de simulación

El bucle `for` que recorre todas las muestras temporales. Se establecen las velocidad don la matriz de pasos.

```
for k = 1:N
    v = pasos(k, 1);   % velocidad lineal
    w = pasos(k, 2);   % velocidad angular
```

En cada iteración, se actualizan las cordenadas (x,y) y la orientación theta del robot utilizando integración numérica con el método de Euler.

```
    x = x + v * cos(theta) * ts;
    y = y + v * sin(theta) * ts;
    theta = theta + w * ts;
```

Poses

Finalmente, imprimimos las poses del robot en cada paso

```
    fprintf('Paso %2d: x = %.3f, y = %.3f, θ = %.2f°\n', k, x, y, rad2deg(theta));
end
```

```
Paso  1: x = 0.000, y = -5.000, θ = 0.00°
Paso  2: x = 0.000, y = -5.000, θ = 60.00°
Paso  3: x = 0.500, y = -4.134, θ = 60.00°
Paso  4: x = 0.500, y = -4.134, θ = 120.00°
Paso  5: x = 0.000, y = -3.268, θ = 120.00°
Paso  6: x = 0.000, y = -3.268, θ = 180.00°
Paso  7: x = -1.000, y = -3.268, θ = 180.00°
Paso  8: x = -1.000, y = -3.268, θ = 240.00°
Paso  9: x = -1.500, y = -4.134, θ = 240.00°
Paso 10: x = -1.500, y = -4.134, θ = 300.00°
Paso 11: x = -1.000, y = -5.000, θ = 300.00°
Paso 12: x = -1.000, y = -5.000, θ = 360.00°
```

```
% Pose final
fprintf('\nPose final del robot:\n'); fprintf('x = %.3f, y = %.3f, θ = %.2f°\n', x,
y, rad2deg(theta));
```

```
Pose final del robot:
x = -1.000, y = -5.000, θ = 360.00°
```

Ejercicio 2

Parámetros del robot

Se definen las dimensiones físicas del robot, necesarias para calcular las velocidades lineales y angulares a partir de las velocidades de las ruedas.

```
r = 0.1;     % Radio de rueda
L = 0.4;     % Distancia entre ruedas
```

Velocidades angulares de las ruedas

Se asignan las velocidades angulares (rad/s) de cada rueda para la simulación. Estas determinan cómo se mueve el robot en cada instante de tiempo.

```
wR = [4.582; 4.773; 5.291; 5.960; 6.490; -1.168; -1.364; 5.960; 5.291; 4.773;
      4.582; 4.773; 5.291; 5.960; 6.490; 6.686; 6.490; 5.960; 5.291; 4.773; 4.582];
```

```
wL = [1.701; 2.353; 3.676; 4.856; 5.618; 13.735; 13.472; 4.856; 3.676; 2.353;
       1.701; 2.353; 3.676; 4.856; 5.618; 5.881; 5.618; 4.856; 3.676; 2.353; 1.701];
```

Cálculo de velocidades de referencia

A partir de las velocidades angulares de cada rueda, se obtienen las velocidades lineales `u0` y angulares `w0` del robot, usando el modelo cinemático de un robot diferencial.

```
u0 = (r/2) .* (wR + wL);
w0 = (r/L) .* (wR - wL);
```

Tiempo

Se define el nuevo tiempo de muestreo y se interpola para obtener un mayor detalle temporal en la simulación. Esto permite visualizar el comportamiento del robot con más precisión.

```
ts = 0.1;
t_original = 0:1:(length(u0)-1);
t = 0:ts:t_original(end);

% Interpolación para aumentar la resolución temporal
u = interp1(t_original, u0, t, 'linear');
w = interp1(t_original, w0, t, 'linear');

N = length(u);
```

Condiciones iniciales

Se inicializa la posición y orientación del robot en el origen. También se inicializan los vectores para almacenar la evolución de estas variables.

```
x1 = zeros(1,N+1);
y1 = zeros(1,N+1);
phi = zeros(1,N+1);

x1(1) = 0;
y1(1) = 0;
phi(1) = 0;
```

Punto de control

Se definen vectores para registrar la trayectoria del punto de control del robot (el centro del eje entre ruedas).

```
hx = zeros(1,N+1);
hy = zeros(1,N+1);

hx(1) = x1(1);
hy(1) = y1(1);
```

Bucle de simulación

En cada paso de tiempo se actualiza la orientación y posición del robot usando el método de integración de Euler, a partir de las velocidades interpoladas.

```
for k=1:N
    phi(k+1)=phi(k)+w(k)*ts;
    xp1=u(k)*cos(phi(k+1));
    yp1=u(k)*sin(phi(k+1));
    x1(k+1)=x1(k) + xp1*ts ;
    y1(k+1)=y1(k) + yp1*ts ;
    hx(k+1)=x1(k+1);
    hy(k+1)=y1(k+1);
end
```

Resultados

Se imprime el resultado de cada paso de tiempo, incluyendo velocidades y posición/orientación del robot.

```
for k = 1:N
    fprintf('t(s) = %-10.3f | v(m/s) = %-10.3f | w(rad/s) = %-10.3f | x(m) =
%-10.3f | y(m) = %-10.3f phi(rad) = %-10.3f\n', ...
        t(k), u(k), w(k), x1(k), y1(k), phi(k));
end
```

```
t(s) = 0.000      | v(m/s) = 0.314      | w(rad/s) = 0.720      | x(m) = 0.000      | y(m) = 0.000      phi(rad) = 0
t(s) = 0.100      | v(m/s) = 0.318      | w(rad/s) = 0.709      | x(m) = 0.031      | y(m) = 0.002      phi(rad) = 0
t(s) = 0.200      | v(m/s) = 0.323      | w(rad/s) = 0.697      | x(m) = 0.063      | y(m) = 0.007      phi(rad) = 0
t(s) = 0.300      | v(m/s) = 0.327      | w(rad/s) = 0.686      | x(m) = 0.094      | y(m) = 0.014      phi(rad) = 0
t(s) = 0.400      | v(m/s) = 0.331      | w(rad/s) = 0.674      | x(m) = 0.126      | y(m) = 0.023      phi(rad) = 0
t(s) = 0.500      | v(m/s) = 0.335      | w(rad/s) = 0.663      | x(m) = 0.157      | y(m) = 0.034      phi(rad) = 0
t(s) = 0.600      | v(m/s) = 0.339      | w(rad/s) = 0.651      | x(m) = 0.188      | y(m) = 0.047      phi(rad) = 0
t(s) = 0.700      | v(m/s) = 0.344      | w(rad/s) = 0.640      | x(m) = 0.218      | y(m) = 0.063      phi(rad) = 0
t(s) = 0.800      | v(m/s) = 0.348      | w(rad/s) = 0.628      | x(m) = 0.247      | y(m) = 0.081      phi(rad) = 0
t(s) = 0.900      | v(m/s) = 0.352      | w(rad/s) = 0.617      | x(m) = 0.276      | y(m) = 0.101      phi(rad) = 0
t(s) = 1.000      | v(m/s) = 0.356      | w(rad/s) = 0.605      | x(m) = 0.303      | y(m) = 0.123      phi(rad) = 0
t(s) = 1.100      | v(m/s) = 0.366      | w(rad/s) = 0.585      | x(m) = 0.330      | y(m) = 0.146      phi(rad) = 0
t(s) = 1.200      | v(m/s) = 0.375      | w(rad/s) = 0.565      | x(m) = 0.356      | y(m) = 0.172      phi(rad) = 0
t(s) = 1.300      | v(m/s) = 0.384      | w(rad/s) = 0.545      | x(m) = 0.381      | y(m) = 0.200      phi(rad) = 0
t(s) = 1.400      | v(m/s) = 0.393      | w(rad/s) = 0.524      | x(m) = 0.404      | y(m) = 0.230      phi(rad) = 0
t(s) = 1.500      | v(m/s) = 0.402      | w(rad/s) = 0.504      | x(m) = 0.427      | y(m) = 0.262      phi(rad) = 0
t(s) = 1.600      | v(m/s) = 0.412      | w(rad/s) = 0.484      | x(m) = 0.449      | y(m) = 0.296      phi(rad) = 1
t(s) = 1.700      | v(m/s) = 0.421      | w(rad/s) = 0.464      | x(m) = 0.470      | y(m) = 0.332      phi(rad) = 1
t(s) = 1.800      | v(m/s) = 0.430      | w(rad/s) = 0.444      | x(m) = 0.489      | y(m) = 0.369      phi(rad) = 1
t(s) = 1.900      | v(m/s) = 0.439      | w(rad/s) = 0.424      | x(m) = 0.507      | y(m) = 0.408      phi(rad) = 1
t(s) = 2.000      | v(m/s) = 0.448      | w(rad/s) = 0.404      | x(m) = 0.523      | y(m) = 0.449      phi(rad) = 1
t(s) = 2.100      | v(m/s) = 0.458      | w(rad/s) = 0.391      | x(m) = 0.539      | y(m) = 0.491      phi(rad) = 1
t(s) = 2.200      | v(m/s) = 0.467      | w(rad/s) = 0.378      | x(m) = 0.552      | y(m) = 0.535      phi(rad) = 1
t(s) = 2.300      | v(m/s) = 0.476      | w(rad/s) = 0.365      | x(m) = 0.565      | y(m) = 0.580      phi(rad) = 1
t(s) = 2.400      | v(m/s) = 0.485      | w(rad/s) = 0.353      | x(m) = 0.576      | y(m) = 0.626      phi(rad) = 1
t(s) = 2.500      | v(m/s) = 0.495      | w(rad/s) = 0.340      | x(m) = 0.586      | y(m) = 0.674      phi(rad) = 1
t(s) = 2.600      | v(m/s) = 0.504      | w(rad/s) = 0.327      | x(m) = 0.594      | y(m) = 0.722      phi(rad) = 1
t(s) = 2.700      | v(m/s) = 0.513      | w(rad/s) = 0.314      | x(m) = 0.600      | y(m) = 0.772      phi(rad) = 1
t(s) = 2.800      | v(m/s) = 0.522      | w(rad/s) = 0.302      | x(m) = 0.605      | y(m) = 0.823      phi(rad) = 1
t(s) = 2.900      | v(m/s) = 0.532      | w(rad/s) = 0.289      | x(m) = 0.609      | y(m) = 0.875      phi(rad) = 1
t(s) = 3.000      | v(m/s) = 0.541      | w(rad/s) = 0.276      | x(m) = 0.611      | y(m) = 0.929      phi(rad) = 1
t(s) = 3.100      | v(m/s) = 0.547      | w(rad/s) = 0.270      | x(m) = 0.612      | y(m) = 0.983      phi(rad) = 1
t(s) = 3.200      | v(m/s) = 0.554      | w(rad/s) = 0.264      | x(m) = 0.611      | y(m) = 1.037      phi(rad) = 1
t(s) = 3.300      | v(m/s) = 0.560      | w(rad/s) = 0.259      | x(m) = 0.609      | y(m) = 1.093      phi(rad) = 1
t(s) = 3.400      | v(m/s) = 0.567      | w(rad/s) = 0.253      | x(m) = 0.606      | y(m) = 1.149      phi(rad) = 1
```

t(s)	v(m/s)	w(rad/s)	x(m)	y(m)	phi(rad)
t(s) = 3.500	v(m/s) = 0.573	w(rad/s) = 0.247	x(m) = 0.600	y(m) = 1.205	phi(rad) = 1
t(s) = 3.600	v(m/s) = 0.580	w(rad/s) = 0.241	x(m) = 0.594	y(m) = 1.262	phi(rad) = 1
t(s) = 3.700	v(m/s) = 0.586	w(rad/s) = 0.235	x(m) = 0.586	y(m) = 1.319	phi(rad) = 1
t(s) = 3.800	v(m/s) = 0.592	w(rad/s) = 0.230	x(m) = 0.576	y(m) = 1.377	phi(rad) = 1
t(s) = 3.900	v(m/s) = 0.599	w(rad/s) = 0.224	x(m) = 0.565	y(m) = 1.435	phi(rad) = 1
t(s) = 4.000	v(m/s) = 0.605	w(rad/s) = 0.218	x(m) = 0.553	y(m) = 1.494	phi(rad) = 1
t(s) = 4.100	v(m/s) = 0.608	w(rad/s) = -0.176	x(m) = 0.539	y(m) = 1.553	phi(rad) = 1
t(s) = 4.200	v(m/s) = 0.610	w(rad/s) = -0.571	x(m) = 0.526	y(m) = 1.612	phi(rad) = 1
t(s) = 4.300	v(m/s) = 0.612	w(rad/s) = -0.965	x(m) = 0.517	y(m) = 1.673	phi(rad) = 1
t(s) = 4.400	v(m/s) = 0.615	w(rad/s) = -1.360	x(m) = 0.513	y(m) = 1.734	phi(rad) = 1
t(s) = 4.500	v(m/s) = 0.617	w(rad/s) = -1.754	x(m) = 0.518	y(m) = 1.795	phi(rad) = 1
t(s) = 4.600	v(m/s) = 0.619	w(rad/s) = -2.148	x(m) = 0.534	y(m) = 1.855	phi(rad) = 1
t(s) = 4.700	v(m/s) = 0.621	w(rad/s) = -2.543	x(m) = 0.561	y(m) = 1.910	phi(rad) = 1
t(s) = 4.800	v(m/s) = 0.624	w(rad/s) = -2.937	x(m) = 0.603	y(m) = 1.957	phi(rad) = 0
t(s) = 4.900	v(m/s) = 0.626	w(rad/s) = -3.331	x(m) = 0.656	y(m) = 1.990	phi(rad) = 0
t(s) = 5.000	v(m/s) = 0.628	w(rad/s) = -3.726	x(m) = 0.717	y(m) = 2.003	phi(rad) = 0
t(s) = 5.100	v(m/s) = 0.626	w(rad/s) = -3.724	x(m) = 0.779	y(m) = 1.994	phi(rad) = -
t(s) = 5.200	v(m/s) = 0.624	w(rad/s) = -3.722	x(m) = 0.833	y(m) = 1.963	phi(rad) = -
t(s) = 5.300	v(m/s) = 0.621	w(rad/s) = -3.721	x(m) = 0.872	y(m) = 1.914	phi(rad) = -
t(s) = 5.400	v(m/s) = 0.619	w(rad/s) = -3.719	x(m) = 0.891	y(m) = 1.855	phi(rad) = -
t(s) = 5.500	v(m/s) = 0.617	w(rad/s) = -3.717	x(m) = 0.886	y(m) = 1.793	phi(rad) = -
t(s) = 5.600	v(m/s) = 0.615	w(rad/s) = -3.716	x(m) = 0.860	y(m) = 1.737	phi(rad) = -
t(s) = 5.700	v(m/s) = 0.612	w(rad/s) = -3.714	x(m) = 0.816	y(m) = 1.695	phi(rad) = -
t(s) = 5.800	v(m/s) = 0.610	w(rad/s) = -3.712	x(m) = 0.759	y(m) = 1.672	phi(rad) = -
t(s) = 5.900	v(m/s) = 0.608	w(rad/s) = -3.711	x(m) = 0.698	y(m) = 1.671	phi(rad) = -
t(s) = 6.000	v(m/s) = 0.605	w(rad/s) = -3.709	x(m) = 0.641	y(m) = 1.692	phi(rad) = -
t(s) = 6.100	v(m/s) = 0.599	w(rad/s) = -3.310	x(m) = 0.596	y(m) = 1.732	phi(rad) = -
t(s) = 6.200	v(m/s) = 0.592	w(rad/s) = -2.912	x(m) = 0.566	y(m) = 1.784	phi(rad) = -
t(s) = 6.300	v(m/s) = 0.586	w(rad/s) = -2.513	x(m) = 0.553	y(m) = 1.842	phi(rad) = -
t(s) = 6.400	v(m/s) = 0.580	w(rad/s) = -2.115	x(m) = 0.555	y(m) = 1.900	phi(rad) = -
t(s) = 6.500	v(m/s) = 0.573	w(rad/s) = -1.716	x(m) = 0.568	y(m) = 1.957	phi(rad) = -
t(s) = 6.600	v(m/s) = 0.567	w(rad/s) = -1.318	x(m) = 0.591	y(m) = 2.009	phi(rad) = -
t(s) = 6.700	v(m/s) = 0.560	w(rad/s) = -0.919	x(m) = 0.621	y(m) = 2.058	phi(rad) = -
t(s) = 6.800	v(m/s) = 0.554	w(rad/s) = -0.521	x(m) = 0.654	y(m) = 2.103	phi(rad) = -
t(s) = 6.900	v(m/s) = 0.547	w(rad/s) = -0.122	x(m) = 0.689	y(m) = 2.146	phi(rad) = -
t(s) = 7.000	v(m/s) = 0.541	w(rad/s) = 0.276	x(m) = 0.724	y(m) = 2.188	phi(rad) = -
t(s) = 7.100	v(m/s) = 0.532	w(rad/s) = 0.289	x(m) = 0.758	y(m) = 2.230	phi(rad) = -
t(s) = 7.200	v(m/s) = 0.522	w(rad/s) = 0.302	x(m) = 0.790	y(m) = 2.272	phi(rad) = -
t(s) = 7.300	v(m/s) = 0.513	w(rad/s) = 0.314	x(m) = 0.820	y(m) = 2.315	phi(rad) = -
t(s) = 7.400	v(m/s) = 0.504	w(rad/s) = 0.327	x(m) = 0.848	y(m) = 2.358	phi(rad) = -
t(s) = 7.500	v(m/s) = 0.495	w(rad/s) = 0.340	x(m) = 0.874	y(m) = 2.401	phi(rad) = -
t(s) = 7.600	v(m/s) = 0.485	w(rad/s) = 0.353	x(m) = 0.898	y(m) = 2.444	phi(rad) = -
t(s) = 7.700	v(m/s) = 0.476	w(rad/s) = 0.365	x(m) = 0.921	y(m) = 2.487	phi(rad) = -
t(s) = 7.800	v(m/s) = 0.467	w(rad/s) = 0.378	x(m) = 0.941	y(m) = 2.530	phi(rad) = -
t(s) = 7.900	v(m/s) = 0.458	w(rad/s) = 0.391	x(m) = 0.960	y(m) = 2.573	phi(rad) = -
t(s) = 8.000	v(m/s) = 0.448	w(rad/s) = 0.404	x(m) = 0.976	y(m) = 2.616	phi(rad) = -
t(s) = 8.100	v(m/s) = 0.439	w(rad/s) = 0.424	x(m) = 0.990	y(m) = 2.658	phi(rad) = -
t(s) = 8.200	v(m/s) = 0.430	w(rad/s) = 0.444	x(m) = 1.003	y(m) = 2.700	phi(rad) = -
t(s) = 8.300	v(m/s) = 0.421	w(rad/s) = 0.464	x(m) = 1.013	y(m) = 2.742	phi(rad) = -
t(s) = 8.400	v(m/s) = 0.412	w(rad/s) = 0.484	x(m) = 1.021	y(m) = 2.784	phi(rad) = -
t(s) = 8.500	v(m/s) = 0.402	w(rad/s) = 0.504	x(m) = 1.027	y(m) = 2.824	phi(rad) = -
t(s) = 8.600	v(m/s) = 0.393	w(rad/s) = 0.524	x(m) = 1.030	y(m) = 2.864	phi(rad) = -
t(s) = 8.700	v(m/s) = 0.384	w(rad/s) = 0.545	x(m) = 1.032	y(m) = 2.904	phi(rad) = -
t(s) = 8.800	v(m/s) = 0.375	w(rad/s) = 0.565	x(m) = 1.031	y(m) = 2.942	phi(rad) = -
t(s) = 8.900	v(m/s) = 0.366	w(rad/s) = 0.585	x(m) = 1.029	y(m) = 2.979	phi(rad) = -
t(s) = 9.000	v(m/s) = 0.356	w(rad/s) = 0.605	x(m) = 1.024	y(m) = 3.016	phi(rad) = -
t(s) = 9.100	v(m/s) = 0.352	w(rad/s) = 0.617	x(m) = 1.017	y(m) = 3.051	phi(rad) = -
t(s) = 9.200	v(m/s) = 0.348	w(rad/s) = 0.628	x(m) = 1.009	y(m) = 3.085	phi(rad) = -
t(s) = 9.300	v(m/s) = 0.344	w(rad/s) = 0.640	x(m) = 0.998	y(m) = 3.118	phi(rad) = -
t(s) = 9.400	v(m/s) = 0.339	w(rad/s) = 0.651	x(m) = 0.985	y(m) = 3.150	phi(rad) = -
t(s) = 9.500	v(m/s) = 0.335	w(rad/s) = 0.663	x(m) = 0.971	y(m) = 3.180	phi(rad) = -
t(s) = 9.600	v(m/s) = 0.331	w(rad/s) = 0.674	x(m) = 0.954	y(m) = 3.210	phi(rad) = -
t(s) = 9.700	v(m/s) = 0.327	w(rad/s) = 0.686	x(m) = 0.936	y(m) = 3.237	phi(rad) = -
t(s) = 9.800	v(m/s) = 0.323	w(rad/s) = 0.697	x(m) = 0.917	y(m) = 3.264	phi(rad) = -

t(s) = 9.900	v(m/s) = 0.318	w(rad/s) = 0.709	x(m) = 0.896	y(m) = 3.288	phi(rad) =
t(s) = 10.000	v(m/s) = 0.314	w(rad/s) = 0.720	x(m) = 0.873	y(m) = 3.310	phi(rad) =
t(s) = 10.100	v(m/s) = 0.318	w(rad/s) = 0.709	x(m) = 0.849	y(m) = 3.331	phi(rad) =
t(s) = 10.200	v(m/s) = 0.323	w(rad/s) = 0.697	x(m) = 0.824	y(m) = 3.350	phi(rad) =
t(s) = 10.300	v(m/s) = 0.327	w(rad/s) = 0.686	x(m) = 0.797	y(m) = 3.368	phi(rad) =
t(s) = 10.400	v(m/s) = 0.331	w(rad/s) = 0.674	x(m) = 0.768	y(m) = 3.383	phi(rad) =
t(s) = 10.500	v(m/s) = 0.335	w(rad/s) = 0.663	x(m) = 0.738	y(m) = 3.397	phi(rad) =
t(s) = 10.600	v(m/s) = 0.339	w(rad/s) = 0.651	x(m) = 0.707	y(m) = 3.410	phi(rad) =
t(s) = 10.700	v(m/s) = 0.344	w(rad/s) = 0.640	x(m) = 0.675	y(m) = 3.420	phi(rad) =
t(s) = 10.800	v(m/s) = 0.348	w(rad/s) = 0.628	x(m) = 0.641	y(m) = 3.428	phi(rad) =
t(s) = 10.900	v(m/s) = 0.352	w(rad/s) = 0.617	x(m) = 0.607	y(m) = 3.434	phi(rad) =
t(s) = 11.000	v(m/s) = 0.356	w(rad/s) = 0.605	x(m) = 0.572	y(m) = 3.438	phi(rad) =
t(s) = 11.100	v(m/s) = 0.366	w(rad/s) = 0.585	x(m) = 0.536	y(m) = 3.440	phi(rad) =
t(s) = 11.200	v(m/s) = 0.375	w(rad/s) = 0.565	x(m) = 0.500	y(m) = 3.440	phi(rad) =
t(s) = 11.300	v(m/s) = 0.384	w(rad/s) = 0.545	x(m) = 0.462	y(m) = 3.438	phi(rad) =
t(s) = 11.400	v(m/s) = 0.393	w(rad/s) = 0.524	x(m) = 0.424	y(m) = 3.434	phi(rad) =
t(s) = 11.500	v(m/s) = 0.402	w(rad/s) = 0.504	x(m) = 0.386	y(m) = 3.427	phi(rad) =
t(s) = 11.600	v(m/s) = 0.412	w(rad/s) = 0.484	x(m) = 0.346	y(m) = 3.419	phi(rad) =
t(s) = 11.700	v(m/s) = 0.421	w(rad/s) = 0.464	x(m) = 0.307	y(m) = 3.408	phi(rad) =
t(s) = 11.800	v(m/s) = 0.430	w(rad/s) = 0.444	x(m) = 0.266	y(m) = 3.395	phi(rad) =
t(s) = 11.900	v(m/s) = 0.439	w(rad/s) = 0.424	x(m) = 0.226	y(m) = 3.380	phi(rad) =
t(s) = 12.000	v(m/s) = 0.448	w(rad/s) = 0.404	x(m) = 0.186	y(m) = 3.363	phi(rad) =
t(s) = 12.100	v(m/s) = 0.458	w(rad/s) = 0.391	x(m) = 0.145	y(m) = 3.344	phi(rad) =
t(s) = 12.200	v(m/s) = 0.467	w(rad/s) = 0.378	x(m) = 0.104	y(m) = 3.323	phi(rad) =
t(s) = 12.300	v(m/s) = 0.476	w(rad/s) = 0.365	x(m) = 0.064	y(m) = 3.300	phi(rad) =
t(s) = 12.400	v(m/s) = 0.485	w(rad/s) = 0.353	x(m) = 0.023	y(m) = 3.275	phi(rad) =
t(s) = 12.500	v(m/s) = 0.495	w(rad/s) = 0.340	x(m) = -0.017	y(m) = 3.248	phi(rad) =
t(s) = 12.600	v(m/s) = 0.504	w(rad/s) = 0.327	x(m) = -0.057	y(m) = 3.219	phi(rad) =
t(s) = 12.700	v(m/s) = 0.513	w(rad/s) = 0.314	x(m) = -0.097	y(m) = 3.189	phi(rad) =
t(s) = 12.800	v(m/s) = 0.522	w(rad/s) = 0.302	x(m) = -0.137	y(m) = 3.156	phi(rad) =
t(s) = 12.900	v(m/s) = 0.532	w(rad/s) = 0.289	x(m) = -0.177	y(m) = 3.122	phi(rad) =
t(s) = 13.000	v(m/s) = 0.541	w(rad/s) = 0.276	x(m) = -0.216	y(m) = 3.086	phi(rad) =
t(s) = 13.100	v(m/s) = 0.547	w(rad/s) = 0.270	x(m) = -0.255	y(m) = 3.048	phi(rad) =
t(s) = 13.200	v(m/s) = 0.554	w(rad/s) = 0.264	x(m) = -0.293	y(m) = 3.009	phi(rad) =
t(s) = 13.300	v(m/s) = 0.560	w(rad/s) = 0.259	x(m) = -0.330	y(m) = 2.969	phi(rad) =
t(s) = 13.400	v(m/s) = 0.567	w(rad/s) = 0.253	x(m) = -0.367	y(m) = 2.927	phi(rad) =
t(s) = 13.500	v(m/s) = 0.573	w(rad/s) = 0.247	x(m) = -0.404	y(m) = 2.883	phi(rad) =
t(s) = 13.600	v(m/s) = 0.580	w(rad/s) = 0.241	x(m) = -0.439	y(m) = 2.838	phi(rad) =
t(s) = 13.700	v(m/s) = 0.586	w(rad/s) = 0.235	x(m) = -0.474	y(m) = 2.792	phi(rad) =
t(s) = 13.800	v(m/s) = 0.592	w(rad/s) = 0.230	x(m) = -0.508	y(m) = 2.744	phi(rad) =
t(s) = 13.900	v(m/s) = 0.599	w(rad/s) = 0.224	x(m) = -0.542	y(m) = 2.695	phi(rad) =
t(s) = 14.000	v(m/s) = 0.605	w(rad/s) = 0.218	x(m) = -0.574	y(m) = 2.645	phi(rad) =
t(s) = 14.100	v(m/s) = 0.608	w(rad/s) = 0.216	x(m) = -0.606	y(m) = 2.594	phi(rad) =
t(s) = 14.200	v(m/s) = 0.610	w(rad/s) = 0.215	x(m) = -0.637	y(m) = 2.541	phi(rad) =
t(s) = 14.300	v(m/s) = 0.612	w(rad/s) = 0.213	x(m) = -0.667	y(m) = 2.488	phi(rad) =
t(s) = 14.400	v(m/s) = 0.615	w(rad/s) = 0.211	x(m) = -0.696	y(m) = 2.434	phi(rad) =
t(s) = 14.500	v(m/s) = 0.617	w(rad/s) = 0.210	x(m) = -0.724	y(m) = 2.379	phi(rad) =
t(s) = 14.600	v(m/s) = 0.619	w(rad/s) = 0.208	x(m) = -0.751	y(m) = 2.324	phi(rad) =
t(s) = 14.700	v(m/s) = 0.621	w(rad/s) = 0.206	x(m) = -0.776	y(m) = 2.267	phi(rad) =
t(s) = 14.800	v(m/s) = 0.624	w(rad/s) = 0.205	x(m) = -0.801	y(m) = 2.210	phi(rad) =
t(s) = 14.900	v(m/s) = 0.626	w(rad/s) = 0.203	x(m) = -0.824	y(m) = 2.153	phi(rad) =
t(s) = 15.000	v(m/s) = 0.628	w(rad/s) = 0.201	x(m) = -0.847	y(m) = 2.094	phi(rad) =
t(s) = 15.100	v(m/s) = 0.626	w(rad/s) = 0.203	x(m) = -0.868	y(m) = 2.035	phi(rad) =
t(s) = 15.200	v(m/s) = 0.624	w(rad/s) = 0.205	x(m) = -0.888	y(m) = 1.976	phi(rad) =
t(s) = 15.300	v(m/s) = 0.621	w(rad/s) = 0.206	x(m) = -0.907	y(m) = 1.916	phi(rad) =
t(s) = 15.400	v(m/s) = 0.619	w(rad/s) = 0.208	x(m) = -0.925	y(m) = 1.857	phi(rad) =
t(s) = 15.500	v(m/s) = 0.617	w(rad/s) = 0.210	x(m) = -0.941	y(m) = 1.797	phi(rad) =
t(s) = 15.600	v(m/s) = 0.615	w(rad/s) = 0.211	x(m) = -0.956	y(m) = 1.737	phi(rad) =
t(s) = 15.700	v(m/s) = 0.612	w(rad/s) = 0.213	x(m) = -0.969	y(m) = 1.677	phi(rad) =
t(s) = 15.800	v(m/s) = 0.610	w(rad/s) = 0.215	x(m) = -0.981	y(m) = 1.617	phi(rad) =
t(s) = 15.900	v(m/s) = 0.608	w(rad/s) = 0.216	x(m) = -0.992	y(m) = 1.557	phi(rad) =
t(s) = 16.000	v(m/s) = 0.605	w(rad/s) = 0.218	x(m) = -1.002	y(m) = 1.497	phi(rad) =
t(s) = 16.100	v(m/s) = 0.599	w(rad/s) = 0.224	x(m) = -1.010	y(m) = 1.437	phi(rad) =
t(s) = 16.200	v(m/s) = 0.592	w(rad/s) = 0.230	x(m) = -1.017	y(m) = 1.378	phi(rad) =

```
t(s) = 16.300     | v(m/s) = 0.586     | w(rad/s) = 0.235     | x(m) = -1.022     | y(m) = 1.319     phi(rad) =
t(s) = 16.400     | v(m/s) = 0.580     | w(rad/s) = 0.241     | x(m) = -1.026     | y(m) = 1.260     phi(rad) =
t(s) = 16.500     | v(m/s) = 0.573     | w(rad/s) = 0.247     | x(m) = -1.029     | y(m) = 1.202     phi(rad) =
t(s) = 16.600     | v(m/s) = 0.567     | w(rad/s) = 0.253     | x(m) = -1.030     | y(m) = 1.145     phi(rad) =
t(s) = 16.700     | v(m/s) = 0.560     | w(rad/s) = 0.259     | x(m) = -1.029     | y(m) = 1.088     phi(rad) =
t(s) = 16.800     | v(m/s) = 0.554     | w(rad/s) = 0.264     | x(m) = -1.028     | y(m) = 1.032     phi(rad) =
t(s) = 16.900     | v(m/s) = 0.547     | w(rad/s) = 0.270     | x(m) = -1.024     | y(m) = 0.977     phi(rad) =
t(s) = 17.000     | v(m/s) = 0.541     | w(rad/s) = 0.276     | x(m) = -1.020     | y(m) = 0.922     phi(rad) =
t(s) = 17.100     | v(m/s) = 0.532     | w(rad/s) = 0.289     | x(m) = -1.013     | y(m) = 0.869     phi(rad) =
t(s) = 17.200     | v(m/s) = 0.522     | w(rad/s) = 0.302     | x(m) = -1.006     | y(m) = 0.816     phi(rad) =
t(s) = 17.300     | v(m/s) = 0.513     | w(rad/s) = 0.314     | x(m) = -0.997     | y(m) = 0.765     phi(rad) =
t(s) = 17.400     | v(m/s) = 0.504     | w(rad/s) = 0.327     | x(m) = -0.986     | y(m) = 0.714     phi(rad) =
t(s) = 17.500     | v(m/s) = 0.495     | w(rad/s) = 0.340     | x(m) = -0.975     | y(m) = 0.665     phi(rad) =
t(s) = 17.600     | v(m/s) = 0.485     | w(rad/s) = 0.353     | x(m) = -0.961     | y(m) = 0.618     phi(rad) =
t(s) = 17.700     | v(m/s) = 0.476     | w(rad/s) = 0.365     | x(m) = -0.947     | y(m) = 0.572     phi(rad) =
t(s) = 17.800     | v(m/s) = 0.467     | w(rad/s) = 0.378     | x(m) = -0.931     | y(m) = 0.527     phi(rad) =
t(s) = 17.900     | v(m/s) = 0.458     | w(rad/s) = 0.391     | x(m) = -0.913     | y(m) = 0.483     phi(rad) =
t(s) = 18.000     | v(m/s) = 0.448     | w(rad/s) = 0.404     | x(m) = -0.895     | y(m) = 0.442     phi(rad) =
t(s) = 18.100     | v(m/s) = 0.439     | w(rad/s) = 0.424     | x(m) = -0.875     | y(m) = 0.401     phi(rad) =
t(s) = 18.200     | v(m/s) = 0.430     | w(rad/s) = 0.444     | x(m) = -0.854     | y(m) = 0.363     phi(rad) =
t(s) = 18.300     | v(m/s) = 0.421     | w(rad/s) = 0.464     | x(m) = -0.831     | y(m) = 0.326     phi(rad) =
t(s) = 18.400     | v(m/s) = 0.412     | w(rad/s) = 0.484     | x(m) = -0.808     | y(m) = 0.291     phi(rad) =
t(s) = 18.500     | v(m/s) = 0.402     | w(rad/s) = 0.504     | x(m) = -0.783     | y(m) = 0.258     phi(rad) =
t(s) = 18.600     | v(m/s) = 0.393     | w(rad/s) = 0.525     | x(m) = -0.758     | y(m) = 0.227     phi(rad) =
t(s) = 18.700     | v(m/s) = 0.384     | w(rad/s) = 0.545     | x(m) = -0.731     | y(m) = 0.198     phi(rad) =
t(s) = 18.800     | v(m/s) = 0.375     | w(rad/s) = 0.565     | x(m) = -0.703     | y(m) = 0.172     phi(rad) =
t(s) = 18.900     | v(m/s) = 0.366     | w(rad/s) = 0.585     | x(m) = -0.675     | y(m) = 0.147     phi(rad) =
t(s) = 19.000     | v(m/s) = 0.356     | w(rad/s) = 0.605     | x(m) = -0.646     | y(m) = 0.125     phi(rad) =
t(s) = 19.100     | v(m/s) = 0.352     | w(rad/s) = 0.617     | x(m) = -0.617     | y(m) = 0.105     phi(rad) =
t(s) = 19.200     | v(m/s) = 0.348     | w(rad/s) = 0.628     | x(m) = -0.586     | y(m) = 0.087     phi(rad) =
t(s) = 19.300     | v(m/s) = 0.344     | w(rad/s) = 0.640     | x(m) = -0.555     | y(m) = 0.071     phi(rad) =
t(s) = 19.400     | v(m/s) = 0.339     | w(rad/s) = 0.651     | x(m) = -0.524     | y(m) = 0.057     phi(rad) =
t(s) = 19.500     | v(m/s) = 0.335     | w(rad/s) = 0.663     | x(m) = -0.492     | y(m) = 0.046     phi(rad) =
t(s) = 19.600     | v(m/s) = 0.331     | w(rad/s) = 0.674     | x(m) = -0.460     | y(m) = 0.037     phi(rad) =
t(s) = 19.700     | v(m/s) = 0.327     | w(rad/s) = 0.686     | x(m) = -0.427     | y(m) = 0.030     phi(rad) =
t(s) = 19.800     | v(m/s) = 0.323     | w(rad/s) = 0.697     | x(m) = -0.395     | y(m) = 0.025     phi(rad) =
t(s) = 19.900     | v(m/s) = 0.318     | w(rad/s) = 0.709     | x(m) = -0.363     | y(m) = 0.023     phi(rad) =
t(s) = 20.000     | v(m/s) = 0.314     | w(rad/s) = 0.720     | x(m) = -0.331     | y(m) = 0.023     phi(rad) = 0
```

Simulación 3D

Se configura una escena en 3D donde se observa el movimiento del robot en el plano XY. Se utiliza una figura gráfica que se actualiza en cada iteración del bucle para animar la trayectoria del robot.

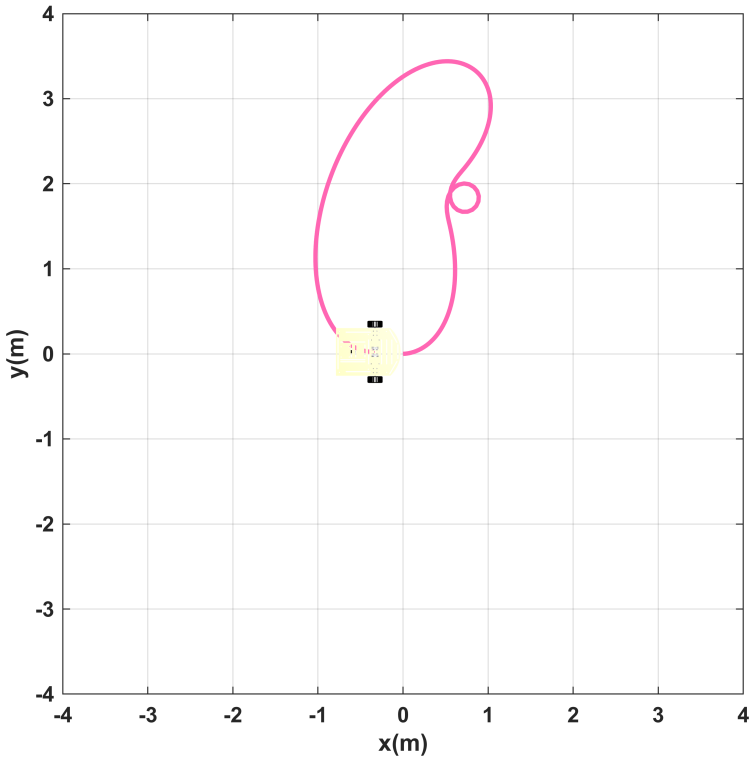
```
scene=figure;
set(scene,'Color','white');
set(gca,'FontWeight','bold') ;
sizeScreen=get(0,'ScreenSize');
set(scene,'position',sizeScreen);
camlight('headlight');
axis equal;
grid on;
box on;
xlabel('x(m)'); ylabel('y(m)'); zlabel('z(m)');
view([0 90]);
axis([-4 4 -4 4 0 2]);

scale = 4;
MobileRobot_5;
```

```
H1=MobilePlot_4(x1(1),y1(1),phi(1),scale);hold on;
H2=plot3(hx(1),hy(1),0,'r','lineWidth',2);

step=1;

for k=1:step:N
    delete(H1);
    delete(H2);
    H1=MobilePlot_4(x1(k),y1(k),phi(k),scale);
    H2=plot3(hx(1:k),hy(1:k),zeros(1,k),'Color', [1 0.4 0.7],'lineWidth',2);
    pause(ts);
end
```

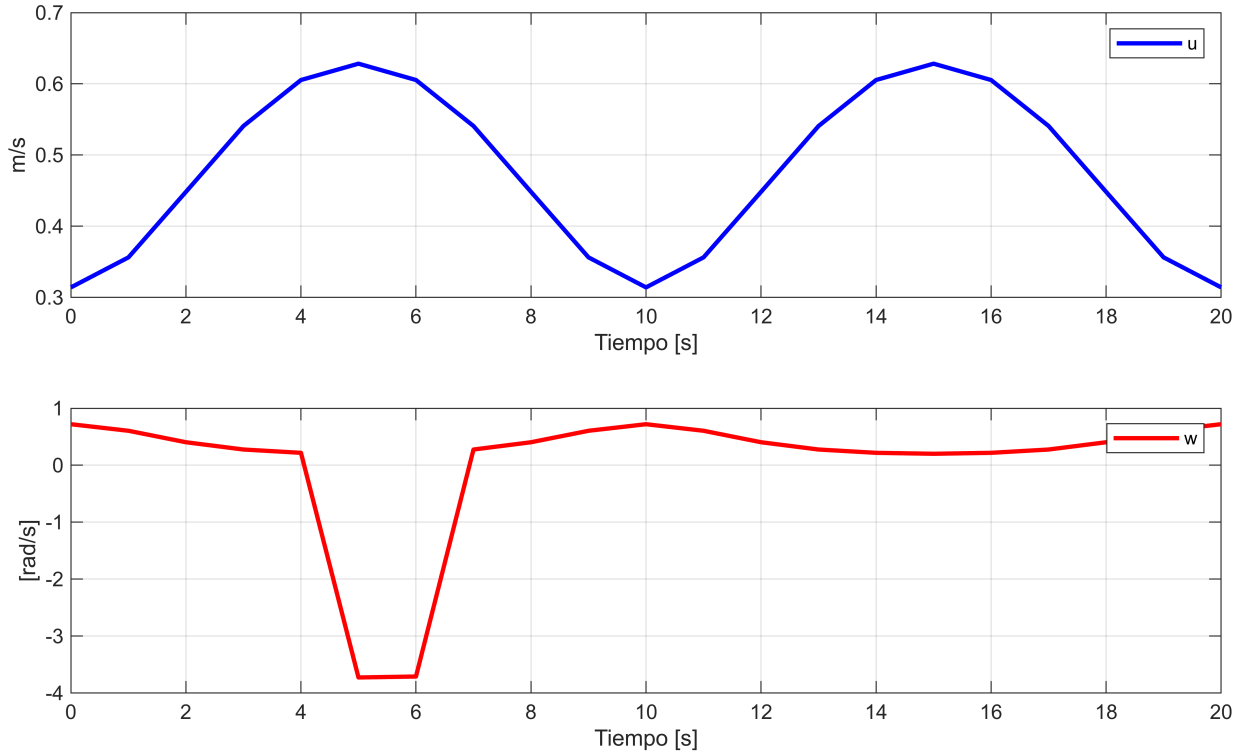


Gráficas

Se visualizan las velocidades de referencia del robot (lineal y angular) y su evolución temporal en posición (x, y) y orientación (phi).

```
graph=figure;
set(graph,'position',sizeScreen);

subplot(211)
plot(t,u,'b','LineWidth',2),grid('on'),xlabel('Tiempo [s]'),ylabel('m/
s'),legend('u');
subplot(212)
plot(t,w,'r','LineWidth',2),grid('on'),xlabel('Tiempo [s]'),ylabel('[rad/
s]'),legend('w');
```

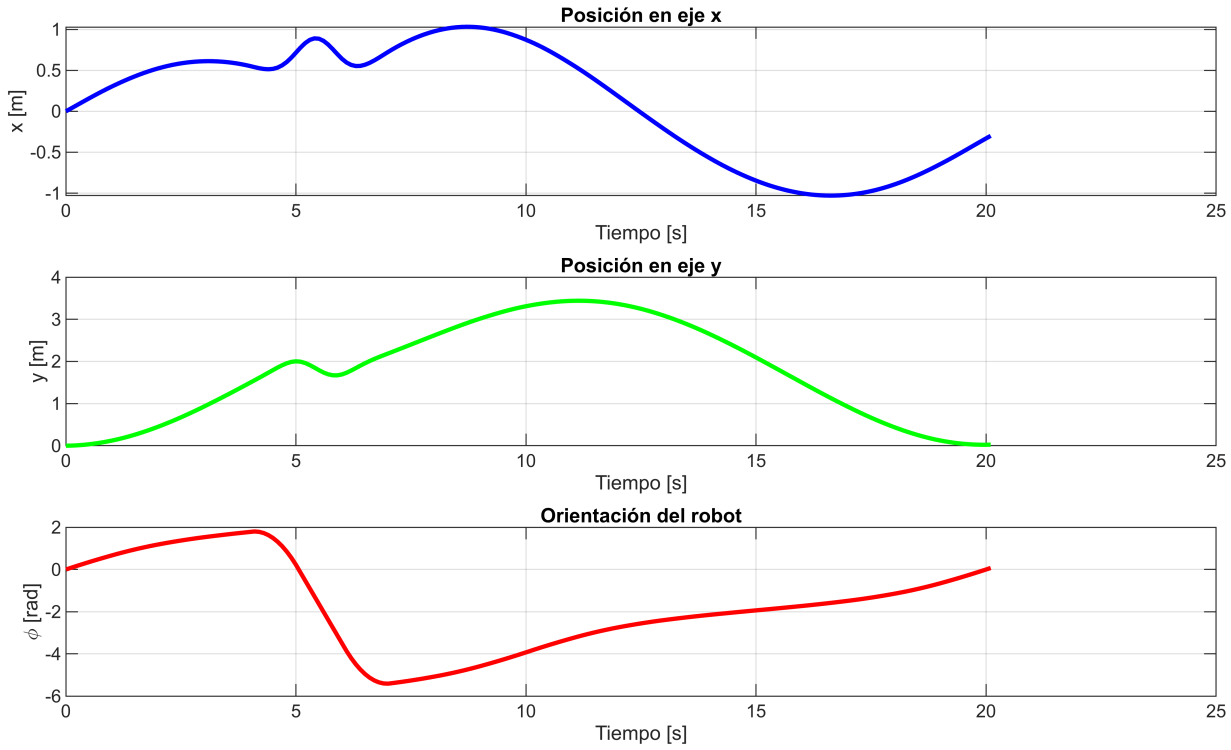



```
figure;
set(gcf,'position',sizeScreen);

subplot(3,1,1)
plot((0:N)*ts, x1, 'b', 'LineWidth', 2);
xlabel('Tiempo [s]'); ylabel('x [m]');
title('Posición en eje x');
grid on;

subplot(3,1,2)
plot((0:N)*ts, y1, 'g', 'LineWidth', 2);
xlabel('Tiempo [s]'); ylabel('y [m]');
title('Posición en eje y');
grid on;

subplot(3,1,3)
plot((0:N)*ts, phi, 'r', 'LineWidth', 2);
xlabel('Tiempo [s]'); ylabel('\phi [rad]');
title('Orientación del robot');
grid on;
```



Ejercicio 3

Velocidades de referencia

En esta simulación, el robot se mueve con una velocidad lineal constante de 4 m/s mientras gira continuamente con una velocidad angular constante de 1 rad/s. Este tipo de movimiento genera una trayectoria circular, lo que permite observar el comportamiento del robot al combinar traslación uniforme con una rotación sostenida.

```
u = 20*ones(1, 640);
w = 1*ones(1, 640);
```

Tiempo

A continuación, se establecen los parámetros temporales. El número de muestras `N` se obtiene a partir de la longitud del vector `u`, mientras que el tiempo de muestreo se define como `ts = 0.01` segundos. El vector de tiempo `t` se genera con una distribución lineal.

```
N = length(u);
tf = N*2;
ts = 0.01;
t = linspace(0, ts, N);
```

Condiciones iniciales

Las condiciones iniciales del robot se fijan en el origen del plano, con orientación cero. Los vectores `x1`, `y1` y `phi` representan respectivamente la posición en el eje X, el eje Y y la orientación del robot a lo largo de toda la simulación.

```
x1 = zeros (1,N+1);
y1 = zeros (1,N+1);
phi = zeros(1, N+1);
```

Asignamos los valores iniciales, correspondientes a la coordenada de inicio, explícitamente en la primera posición de cada vector.

```
x1(1) = 0;
y1(1) = -20;
phi(1) = 0;
```

Punto de control

También se inicializan los vectores `hx` y `hy` que almacenarán la trayectoria del punto de control del robot (que coincide con el centro del eje entre ruedas), comenzando en la misma posición inicial del robot.

```
hx = zeros(1, N+1);
hy = zeros(1, N+1);

hx(1) = x1(1);
hy(1) = y1(1);
```

Bucle de simulación

El bucle `for` que recorre todas las muestras temporales. En cada iteración, se actualiza la orientación `phi` del robot utilizando integración numérica con el método de Euler. Luego, se calculan las componentes de la velocidad en los ejes X y Y considerando la orientación recién calculada. Con esas velocidades, también mediante Euler, se actualiza la posición del robot. Finalmente, se actualiza la trayectoria del punto de control con las nuevas coordenadas del centro del robot.

```
for k=1:N

    phi(k+1)=phi(k)+w(k)*ts; % Integral numérica (método de Euler)

    %%%%%%%%%%%%%%%%%%%% MODELO CINEMATICO %%%%%%%%%%%%%%%%%%%%%%%%

    xp1=u(k)*cos(phi(k+1));
    yp1=u(k)*sin(phi(k+1));

    x1(k+1)=x1(k) + xp1*ts ; % Integral numérica (método de Euler)
    y1(k+1)=y1(k) + yp1*ts ; % Integral numérica (método de Euler)


    % Posicion del robot con respecto al punto de control
    hx(k+1)=x1(k+1);
    hy(k+1)=y1(k+1);
```

```
    wr_k = (2*u(k) + w(k)*L) / (2*r);
    wl_k = (2*u(k) - w(k)*L) / (2*r);
    fprintf('t = %.2f s | ω_R = %.2f rad/s | ω_L = %.2f rad/s\n', k*ts, wr_k, wl_k);

end
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t = 0.01 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
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t = 5.35 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.36 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.37 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.38 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.39 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.40 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.41 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.42 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.43 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.44 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.45 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.46 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.47 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.48 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.49 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.50 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.51 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.52 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.53 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.54 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.55 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.56 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.57 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.58 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.59 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.60 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.61 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.62 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.63 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.64 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.65 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.66 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.67 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.68 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
```

t = 5.69 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.70 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.71 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.72 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.73 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.74 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.75 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.76 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.77 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.78 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.79 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.80 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.81 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.82 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.83 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.84 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.85 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.86 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.87 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.88 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.89 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.90 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.91 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.92 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.93 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.94 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.95 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.96 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.97 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.98 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 5.99 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 6.00 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 6.01 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 6.02 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 6.03 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 6.04 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 6.05 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 6.06 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 6.07 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 6.08 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 6.09 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 6.10 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 6.11 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 6.12 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 6.13 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 6.14 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 6.15 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 6.16 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 6.17 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 6.18 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 6.19 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 6.20 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 6.21 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 6.22 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 6.23 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 6.24 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 6.25 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 6.26 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 6.27 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 6.28 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 6.29 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 6.30 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 6.31 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 6.32 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s

```
t = 6.33 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 6.34 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 6.35 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 6.36 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 6.37 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 6.38 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 6.39 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
t = 6.40 s | ω_R = 202.00 rad/s | ω_L = 198.00 rad/s
```

Simulacion virtual 3D

Tras la simulación cinemática, se configura un entorno 3D para visualizar el comportamiento del robot. Se crea una figura de tamaño completo con fondo blanco, se ajustan los ejes con proporciones iguales y se establecen etiquetas y cuadrículas para facilitar la lectura del entorno. Se coloca una luz en la escena y se orienta la vista para una mejor perspectiva. Los límites de visualización se establecen para acomodar el espacio que recorrerá el robot.

a) Configuracion de escena

```
scene=figure;  % Crear figura (Escena)
set(scene,'Color','white'); % Color del fondo de la escena
set(gca,'FontWeight','bold') ;% Negrilla en los ejes y etiquetas
sizeScreen=get(0,'ScreenSize'); % Retorna el tamaño de la pantalla del computador
set(scene,'position',sizeScreen); % Congigurar tamaño de la figura
camlight('headlight'); % Luz para la escena
axis equal; % Establece la relación de aspecto para que las unidades de datos sean
las mismas en todas las direcciones.
grid on; % Mostrar líneas de cuadrícula en los ejes
box on; % Mostrar contorno de ejes
xlabel('x(m)'); ylabel('y(m)'); zlabel('z(m)'); % Etiqueta de los eje

view([0 90]); % Orientacion de la figura
axis([-21 21 -21 21 0 2]); % Ingresar limites minimos y maximos en los ejes x y z
[minX maxX minY maxY minZ maxZ]
```

b) Graficar robots en la posicion inicial

```
scale = 4;
MobileRobot_5;
H1=MobilePlot_4(x1(1),y1(1),phi(1),scale);hold on;
```

c) Graficar Trayectorias

```
H2=plot3(hx(1),hy(1),0,'c','lineWidth',2);
```

d) Bucle de simulacion de movimiento del robot

Se dibuja el robot en su posición inicial mediante una función externa (`MobilePlot_4`) que toma como parámetros la posición, orientación y una escala de visualización. Luego, se dibuja la primera parte de la trayectoria del punto de control en color rojo. El bucle de simulación gráfica recorre los pasos definidos, actualizando la posición del robot y su trayectoria en cada iteración.

```
step=1; % pasos para simulacion
```

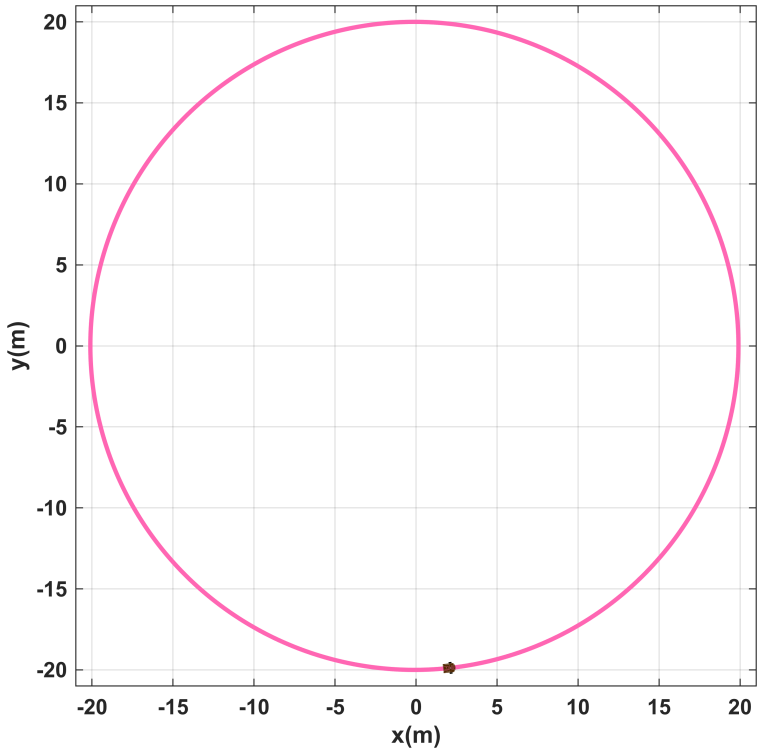
```
for k=1:step:N

    delete(H1);
    delete(H2);

    H1=MobilePlot_4(x1(k),y1(k),phi(k),scale);
    H2=plot3(hx(1:k),hy(1:k),zeros(1,k),'Color', [1 0.4 0.7],'lineWidth',2);

    pause(ts);

end
```



Gráficas

Finalmente, se calculan las velocidades de las ruedas derecha (`wr`) y izquierda (`wl`) utilizando las ecuaciones cinemáticas del robot diferencial, y se crean dos nuevas subgráficas. La primera muestra la velocidad de la rueda derecha, y la segunda, la velocidad de la rueda izquierda.

```
wr = (2*u + w*L) / (2*r);
wl = (2*u - w*L) / (2*r);

graph6 = figure;
set(graph6, 'position', sizeScreen);

subplot(2,1,1)
plot((0:N-1)*ts, wr, 'r', 'LineWidth', 2);
```

```
xlabel('Tiempo [s]'); ylabel('x [m]');
title('Velocidad rueda derecha (WR)');
grid on;

subplot(2,1,2)
plot((0:N-1)*ts, wl, 'b', 'LineWidth', 2);
xlabel('Tiempo [s]'); ylabel('y [m]');
title('Velocidad rueda izquierda (WL)');
grid on;
```