Evaluación: Localización de un robot diferencial

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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 = 10;
```

Pasos

Se establece el historial de pasos descrito en el ejercicio

```
pasos = [
    1.432,   0.0;
    0.0,     2.513;
    1.432,   0.0;
    0.0,     2.513;
    1.432,   0.0;
    0.0,     2.513;
    1.432,   0.0;
    0.0,     2.513;
    1.432,   0.0;
    0.0,     2.513;
];

u = pasos(:,1); % velocidades lineales
w = pasos(:,2); % velocidades angulares
```

Pose inicial

Se define la coordenada y orientación inicial del robot

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

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

```
phi(1) = 0;

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

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

Bucle de simulación

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

```
%% Simulación cinemática (modelo diferencial)
for k = 1:N
    % Actualizar orientación
    phi(k+1) = phi(k) + w(k)*ts;

    % Velocidades en X e Y
    xp1 = u(k) * cos(phi(k+1));
    yp1 = u(k) * sin(phi(k+1));

    % Actualizar posiciones
    x1(k+1) = x1(k) + xp1 * ts;
    y1(k+1) = y1(k) + yp1 * ts;

    % Punto de control
    hx(k+1) = x1(k+1);
    hy(k+1) = y1(k+1);

    theta = mod(phi(k+1), 2*pi);  % Normaliza entre 0 y 2π
```

Poses

Finalmente, imprimimos las poses del robot en cada paso

```
    fprintf('Paso %2d: x = %.3f, y = %.3f, θ = %.2f°\n', k, x1(k+1), y1(k+1),
rad2deg(theta));
end
```

```
Paso  1: x = 1.432, y = 0.000, θ = 0.00°
Paso  2: x = 1.432, y = 0.000, θ = 143.98°
Paso  3: x = 0.274, y = 0.842, θ = 143.98°
Paso  4: x = 0.274, y = 0.842, θ = 287.97°
Paso  5: x = 0.715, y = -0.520, θ = 287.97°
Paso  6: x = 0.715, y = -0.520, θ = 71.95°
Paso  7: x = 1.159, y = 0.841, θ = 71.95°
Paso  8: x = 1.159, y = 0.841, θ = 215.94°
Paso  9: x = -0.000, y = 0.001, θ = 215.94°
Paso 10: x = -0.000, y = 0.001, θ = 359.92°
```

```
%% Escena 3D
scene = figure;
```

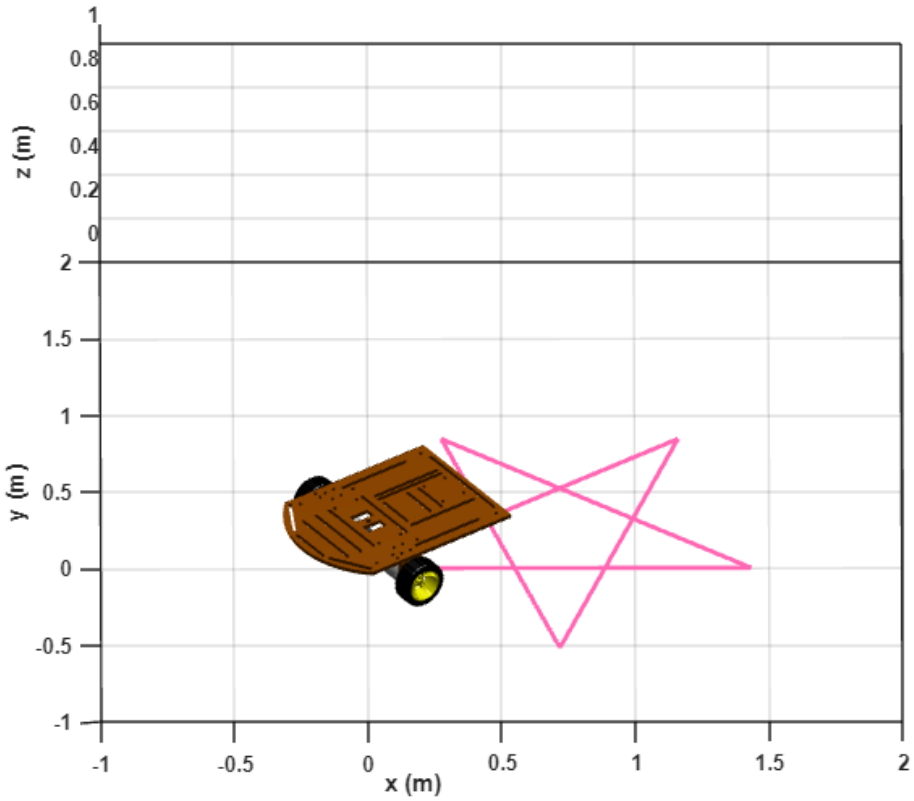
```
set(scene,'Color','white');
set(gca,'FontWeight','bold');
sizeScreen = get(0,'ScreenSize');
set(scene,'Position',sizeScreen);
camlight('headlight');
axis equal;
grid on;
box on;
xlabel('x (m)');
ylabel('y (m)');
zlabel('z (m)');
view([-0.1 35]);
axis([-1 2 -1 2 0 1]);

%% Graficar robot en posición inicial
scale = 4;
MobileRobot_5;
H1 = MobilePlot_4(x1(1), y1(1), phi(1), scale); hold on;
H2 = plot3(hx(1), hy(1), 0, 'c', 'LineWidth', 2);

%% Bucle de animación
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
```




```
% Pose final
fprintf('\nPose final del robot:\n'); fprintf('x = %.3f, y = %.3f, θ = %.2f°\n',
x1(end), y1(end), rad2deg(theta));
```

```
Pose final del robot:
x = -0.000, y = 0.001, θ = 359.92°
```

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 = 0.05;     % Radio de rueda
L = 0.18;     % 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(grados) = %-10.3f°\n', ...
        t(k), u(k), w(k), x1(k), y1(k), rad2deg(phi(k)));
end
```

```
t(s) = 0.000      | v(m/s) = 0.157      | w(rad/s) = 0.800      | x(m) = 0.000      | y(m) = 0.000      phi(grados)
t(s) = 0.100      | v(m/s) = 0.159      | w(rad/s) = 0.787      | x(m) = 0.016      | y(m) = 0.001      phi(grados)
t(s) = 0.200      | v(m/s) = 0.161      | w(rad/s) = 0.775      | x(m) = 0.031      | y(m) = 0.004      phi(grados)
t(s) = 0.300      | v(m/s) = 0.163      | w(rad/s) = 0.762      | x(m) = 0.047      | y(m) = 0.008      phi(grados)
t(s) = 0.400      | v(m/s) = 0.166      | w(rad/s) = 0.749      | x(m) = 0.063      | y(m) = 0.013      phi(grados)
t(s) = 0.500      | v(m/s) = 0.168      | w(rad/s) = 0.736      | x(m) = 0.078      | y(m) = 0.019      phi(grados)
t(s) = 0.600      | v(m/s) = 0.170      | w(rad/s) = 0.723      | x(m) = 0.093      | y(m) = 0.026      phi(grados)
t(s) = 0.700      | v(m/s) = 0.172      | w(rad/s) = 0.711      | x(m) = 0.108      | y(m) = 0.035      phi(grados)
t(s) = 0.800      | v(m/s) = 0.174      | w(rad/s) = 0.698      | x(m) = 0.122      | y(m) = 0.045      phi(grados)
t(s) = 0.900      | v(m/s) = 0.176      | w(rad/s) = 0.685      | x(m) = 0.135      | y(m) = 0.056      phi(grados)
t(s) = 1.000      | v(m/s) = 0.178      | w(rad/s) = 0.672      | x(m) = 0.148      | y(m) = 0.067      phi(grados)
t(s) = 1.100      | v(m/s) = 0.183      | w(rad/s) = 0.650      | x(m) = 0.161      | y(m) = 0.080      phi(grados)
t(s) = 1.200      | v(m/s) = 0.187      | w(rad/s) = 0.627      | x(m) = 0.172      | y(m) = 0.094      phi(grados)
t(s) = 1.300      | v(m/s) = 0.192      | w(rad/s) = 0.605      | x(m) = 0.183      | y(m) = 0.109      phi(grados)
t(s) = 1.400      | v(m/s) = 0.197      | w(rad/s) = 0.583      | x(m) = 0.194      | y(m) = 0.126      phi(grados)
t(s) = 1.500      | v(m/s) = 0.201      | w(rad/s) = 0.560      | x(m) = 0.203      | y(m) = 0.143      phi(grados)
t(s) = 1.600      | v(m/s) = 0.206      | w(rad/s) = 0.538      | x(m) = 0.212      | y(m) = 0.161      phi(grados)
t(s) = 1.700      | v(m/s) = 0.210      | w(rad/s) = 0.516      | x(m) = 0.220      | y(m) = 0.180      phi(grados)
t(s) = 1.800      | v(m/s) = 0.215      | w(rad/s) = 0.493      | x(m) = 0.228      | y(m) = 0.199      phi(grados)
t(s) = 1.900      | v(m/s) = 0.220      | w(rad/s) = 0.471      | x(m) = 0.234      | y(m) = 0.220      phi(grados)
t(s) = 2.000      | v(m/s) = 0.224      | w(rad/s) = 0.449      | x(m) = 0.240      | y(m) = 0.241      phi(grados)
t(s) = 2.100      | v(m/s) = 0.229      | w(rad/s) = 0.434      | x(m) = 0.244      | y(m) = 0.263      phi(grados)
t(s) = 2.200      | v(m/s) = 0.233      | w(rad/s) = 0.420      | x(m) = 0.248      | y(m) = 0.286      phi(grados)
t(s) = 2.300      | v(m/s) = 0.238      | w(rad/s) = 0.406      | x(m) = 0.251      | y(m) = 0.309      phi(grados)
t(s) = 2.400      | v(m/s) = 0.243      | w(rad/s) = 0.392      | x(m) = 0.253      | y(m) = 0.333      phi(grados)
t(s) = 2.500      | v(m/s) = 0.247      | w(rad/s) = 0.378      | x(m) = 0.254      | y(m) = 0.357      phi(grados)
t(s) = 2.600      | v(m/s) = 0.252      | w(rad/s) = 0.363      | x(m) = 0.255      | y(m) = 0.381      phi(grados)
t(s) = 2.700      | v(m/s) = 0.257      | w(rad/s) = 0.349      | x(m) = 0.254      | y(m) = 0.407      phi(grados)
t(s) = 2.800      | v(m/s) = 0.261      | w(rad/s) = 0.335      | x(m) = 0.252      | y(m) = 0.432      phi(grados)
t(s) = 2.900      | v(m/s) = 0.266      | w(rad/s) = 0.321      | x(m) = 0.250      | y(m) = 0.458      phi(grados)
t(s) = 3.000      | v(m/s) = 0.270      | w(rad/s) = 0.307      | x(m) = 0.246      | y(m) = 0.485      phi(grados)
t(s) = 3.100      | v(m/s) = 0.274      | w(rad/s) = 0.300      | x(m) = 0.242      | y(m) = 0.511      phi(grados)
t(s) = 3.200      | v(m/s) = 0.277      | w(rad/s) = 0.294      | x(m) = 0.237      | y(m) = 0.538      phi(grados)
t(s) = 3.300      | v(m/s) = 0.280      | w(rad/s) = 0.287      | x(m) = 0.231      | y(m) = 0.565      phi(grados)
t(s) = 3.400      | v(m/s) = 0.283      | w(rad/s) = 0.281      | x(m) = 0.224      | y(m) = 0.592      phi(grados)
t(s) = 3.500      | v(m/s) = 0.287      | w(rad/s) = 0.274      | x(m) = 0.216      | y(m) = 0.620      phi(grados)
t(s) = 3.600      | v(m/s) = 0.290      | w(rad/s) = 0.268      | x(m) = 0.208      | y(m) = 0.647      phi(grados)
t(s) = 3.700      | v(m/s) = 0.293      | w(rad/s) = 0.262      | x(m) = 0.198      | y(m) = 0.674      phi(grados)
t(s) = 3.800      | v(m/s) = 0.296      | w(rad/s) = 0.255      | x(m) = 0.188      | y(m) = 0.702      phi(grados)
t(s) = 3.900      | v(m/s) = 0.299      | w(rad/s) = 0.249      | x(m) = 0.177      | y(m) = 0.729      phi(grados)
t(s) = 4.000      | v(m/s) = 0.303      | w(rad/s) = 0.242      | x(m) = 0.165      | y(m) = 0.757      phi(grados)
```

t(s) = 4.100	v(m/s) = 0.304	w(rad/s) = -0.196	x(m) = 0.153	y(m) = 0.784	phi(grados)
t(s) = 4.200	v(m/s) = 0.305	w(rad/s) = -0.634	x(m) = 0.141	y(m) = 0.812	phi(grados)
t(s) = 4.300	v(m/s) = 0.306	w(rad/s) = -1.072	x(m) = 0.130	y(m) = 0.841	phi(grados)
t(s) = 4.400	v(m/s) = 0.307	w(rad/s) = -1.511	x(m) = 0.123	y(m) = 0.871	phi(grados)
t(s) = 4.500	v(m/s) = 0.308	w(rad/s) = -1.949	x(m) = 0.120	y(m) = 0.901	phi(grados)
t(s) = 4.600	v(m/s) = 0.310	w(rad/s) = -2.387	x(m) = 0.124	y(m) = 0.932	phi(grados)
t(s) = 4.700	v(m/s) = 0.311	w(rad/s) = -2.825	x(m) = 0.134	y(m) = 0.961	phi(grados)
t(s) = 4.800	v(m/s) = 0.312	w(rad/s) = -3.263	x(m) = 0.152	y(m) = 0.986	phi(grados)
t(s) = 4.900	v(m/s) = 0.313	w(rad/s) = -3.702	x(m) = 0.178	y(m) = 1.004	phi(grados)
t(s) = 5.000	v(m/s) = 0.314	w(rad/s) = -4.140	x(m) = 0.208	y(m) = 1.012	phi(grados)
t(s) = 5.100	v(m/s) = 0.313	w(rad/s) = -4.138	x(m) = 0.239	y(m) = 1.007	phi(grados)
t(s) = 5.200	v(m/s) = 0.312	w(rad/s) = -4.136	x(m) = 0.265	y(m) = 0.990	phi(grados)
t(s) = 5.300	v(m/s) = 0.311	w(rad/s) = -4.134	x(m) = 0.282	y(m) = 0.963	phi(grados)
t(s) = 5.400	v(m/s) = 0.310	w(rad/s) = -4.132	x(m) = 0.287	y(m) = 0.933	phi(grados)
t(s) = 5.500	v(m/s) = 0.308	w(rad/s) = -4.130	x(m) = 0.280	y(m) = 0.903	phi(grados)
t(s) = 5.600	v(m/s) = 0.307	w(rad/s) = -4.129	x(m) = 0.261	y(m) = 0.878	phi(grados)
t(s) = 5.700	v(m/s) = 0.306	w(rad/s) = -4.127	x(m) = 0.234	y(m) = 0.864	phi(grados)
t(s) = 5.800	v(m/s) = 0.305	w(rad/s) = -4.125	x(m) = 0.203	y(m) = 0.861	phi(grados)
t(s) = 5.900	v(m/s) = 0.304	w(rad/s) = -4.123	x(m) = 0.174	y(m) = 0.871	phi(grados)
t(s) = 6.000	v(m/s) = 0.303	w(rad/s) = -4.121	x(m) = 0.152	y(m) = 0.892	phi(grados)
t(s) = 6.100	v(m/s) = 0.299	w(rad/s) = -3.678	x(m) = 0.140	y(m) = 0.919	phi(grados)
t(s) = 6.200	v(m/s) = 0.296	w(rad/s) = -3.236	x(m) = 0.138	y(m) = 0.949	phi(grados)
t(s) = 6.300	v(m/s) = 0.293	w(rad/s) = -2.793	x(m) = 0.146	y(m) = 0.978	phi(grados)
t(s) = 6.400	v(m/s) = 0.290	w(rad/s) = -2.350	x(m) = 0.162	y(m) = 1.003	phi(grados)
t(s) = 6.500	v(m/s) = 0.287	w(rad/s) = -1.907	x(m) = 0.182	y(m) = 1.023	phi(grados)
t(s) = 6.600	v(m/s) = 0.283	w(rad/s) = -1.464	x(m) = 0.206	y(m) = 1.039	phi(grados)
t(s) = 6.700	v(m/s) = 0.280	w(rad/s) = -1.022	x(m) = 0.232	y(m) = 1.051	phi(grados)
t(s) = 6.800	v(m/s) = 0.277	w(rad/s) = -0.579	x(m) = 0.258	y(m) = 1.061	phi(grados)
t(s) = 6.900	v(m/s) = 0.274	w(rad/s) = -0.136	x(m) = 0.285	y(m) = 1.068	phi(grados)
t(s) = 7.000	v(m/s) = 0.270	w(rad/s) = 0.307	x(m) = 0.311	y(m) = 1.076	phi(grados)
t(s) = 7.100	v(m/s) = 0.266	w(rad/s) = 0.321	x(m) = 0.337	y(m) = 1.084	phi(grados)
t(s) = 7.200	v(m/s) = 0.261	w(rad/s) = 0.335	x(m) = 0.362	y(m) = 1.092	phi(grados)
t(s) = 7.300	v(m/s) = 0.257	w(rad/s) = 0.349	x(m) = 0.386	y(m) = 1.102	phi(grados)
t(s) = 7.400	v(m/s) = 0.252	w(rad/s) = 0.363	x(m) = 0.410	y(m) = 1.112	phi(grados)
t(s) = 7.500	v(m/s) = 0.247	w(rad/s) = 0.378	x(m) = 0.433	y(m) = 1.123	phi(grados)
t(s) = 7.600	v(m/s) = 0.243	w(rad/s) = 0.392	x(m) = 0.455	y(m) = 1.134	phi(grados)
t(s) = 7.700	v(m/s) = 0.238	w(rad/s) = 0.406	x(m) = 0.476	y(m) = 1.146	phi(grados)
t(s) = 7.800	v(m/s) = 0.233	w(rad/s) = 0.420	x(m) = 0.496	y(m) = 1.158	phi(grados)
t(s) = 7.900	v(m/s) = 0.229	w(rad/s) = 0.434	x(m) = 0.515	y(m) = 1.171	phi(grados)
t(s) = 8.000	v(m/s) = 0.224	w(rad/s) = 0.449	x(m) = 0.534	y(m) = 1.185	phi(grados)
t(s) = 8.100	v(m/s) = 0.220	w(rad/s) = 0.471	x(m) = 0.551	y(m) = 1.199	phi(grados)
t(s) = 8.200	v(m/s) = 0.215	w(rad/s) = 0.493	x(m) = 0.567	y(m) = 1.214	phi(grados)
t(s) = 8.300	v(m/s) = 0.210	w(rad/s) = 0.516	x(m) = 0.583	y(m) = 1.229	phi(grados)
t(s) = 8.400	v(m/s) = 0.206	w(rad/s) = 0.538	x(m) = 0.597	y(m) = 1.245	phi(grados)
t(s) = 8.500	v(m/s) = 0.201	w(rad/s) = 0.560	x(m) = 0.610	y(m) = 1.261	phi(grados)
t(s) = 8.600	v(m/s) = 0.197	w(rad/s) = 0.583	x(m) = 0.622	y(m) = 1.277	phi(grados)
t(s) = 8.700	v(m/s) = 0.192	w(rad/s) = 0.605	x(m) = 0.632	y(m) = 1.294	phi(grados)
t(s) = 8.800	v(m/s) = 0.187	w(rad/s) = 0.628	x(m) = 0.641	y(m) = 1.310	phi(grados)
t(s) = 8.900	v(m/s) = 0.183	w(rad/s) = 0.650	x(m) = 0.650	y(m) = 1.327	phi(grados)
t(s) = 9.000	v(m/s) = 0.178	w(rad/s) = 0.672	x(m) = 0.656	y(m) = 1.344	phi(grados)
t(s) = 9.100	v(m/s) = 0.176	w(rad/s) = 0.685	x(m) = 0.662	y(m) = 1.361	phi(grados)
t(s) = 9.200	v(m/s) = 0.174	w(rad/s) = 0.698	x(m) = 0.666	y(m) = 1.378	phi(grados)
t(s) = 9.300	v(m/s) = 0.172	w(rad/s) = 0.711	x(m) = 0.669	y(m) = 1.395	phi(grados)
t(s) = 9.400	v(m/s) = 0.170	w(rad/s) = 0.723	x(m) = 0.671	y(m) = 1.412	phi(grados)
t(s) = 9.500	v(m/s) = 0.168	w(rad/s) = 0.736	x(m) = 0.671	y(m) = 1.429	phi(grados)
t(s) = 9.600	v(m/s) = 0.166	w(rad/s) = 0.749	x(m) = 0.671	y(m) = 1.446	phi(grados)
t(s) = 9.700	v(m/s) = 0.163	w(rad/s) = 0.762	x(m) = 0.669	y(m) = 1.463	phi(grados)
t(s) = 9.800	v(m/s) = 0.161	w(rad/s) = 0.775	x(m) = 0.666	y(m) = 1.479	phi(grados)
t(s) = 9.900	v(m/s) = 0.159	w(rad/s) = 0.787	x(m) = 0.661	y(m) = 1.494	phi(grados)
t(s) = 10.000	v(m/s) = 0.157	w(rad/s) = 0.800	x(m) = 0.656	y(m) = 1.509	phi(grados)
t(s) = 10.100	v(m/s) = 0.159	w(rad/s) = 0.787	x(m) = 0.649	y(m) = 1.523	phi(grados)
t(s) = 10.200	v(m/s) = 0.161	w(rad/s) = 0.775	x(m) = 0.642	y(m) = 1.537	phi(grados)
t(s) = 10.300	v(m/s) = 0.163	w(rad/s) = 0.762	x(m) = 0.633	y(m) = 1.551	phi(grados)
t(s) = 10.400	v(m/s) = 0.166	w(rad/s) = 0.749	x(m) = 0.623	y(m) = 1.564	phi(grados)

t(s) = 10.500	v(m/s) = 0.168	w(rad/s) = 0.736	x(m) = 0.612	y(m) = 1.576	phi(grados)
t(s) = 10.600	v(m/s) = 0.170	w(rad/s) = 0.723	x(m) = 0.600	y(m) = 1.587	phi(grados)
t(s) = 10.700	v(m/s) = 0.172	w(rad/s) = 0.711	x(m) = 0.586	y(m) = 1.598	phi(grados)
t(s) = 10.800	v(m/s) = 0.174	w(rad/s) = 0.698	x(m) = 0.572	y(m) = 1.608	phi(grados)
t(s) = 10.900	v(m/s) = 0.176	w(rad/s) = 0.685	x(m) = 0.558	y(m) = 1.617	phi(grados)
t(s) = 11.000	v(m/s) = 0.178	w(rad/s) = 0.672	x(m) = 0.542	y(m) = 1.625	phi(grados)
t(s) = 11.100	v(m/s) = 0.183	w(rad/s) = 0.650	x(m) = 0.526	y(m) = 1.633	phi(grados)
t(s) = 11.200	v(m/s) = 0.187	w(rad/s) = 0.628	x(m) = 0.508	y(m) = 1.639	phi(grados)
t(s) = 11.300	v(m/s) = 0.192	w(rad/s) = 0.605	x(m) = 0.490	y(m) = 1.644	phi(grados)
t(s) = 11.400	v(m/s) = 0.197	w(rad/s) = 0.583	x(m) = 0.472	y(m) = 1.648	phi(grados)
t(s) = 11.500	v(m/s) = 0.201	w(rad/s) = 0.560	x(m) = 0.452	y(m) = 1.651	phi(grados)
t(s) = 11.600	v(m/s) = 0.206	w(rad/s) = 0.538	x(m) = 0.432	y(m) = 1.654	phi(grados)
t(s) = 11.700	v(m/s) = 0.210	w(rad/s) = 0.516	x(m) = 0.412	y(m) = 1.655	phi(grados)
t(s) = 11.800	v(m/s) = 0.215	w(rad/s) = 0.493	x(m) = 0.391	y(m) = 1.655	phi(grados)
t(s) = 11.900	v(m/s) = 0.220	w(rad/s) = 0.471	x(m) = 0.369	y(m) = 1.654	phi(grados)
t(s) = 12.000	v(m/s) = 0.224	w(rad/s) = 0.449	x(m) = 0.347	y(m) = 1.652	phi(grados)
t(s) = 12.100	v(m/s) = 0.229	w(rad/s) = 0.434	x(m) = 0.325	y(m) = 1.649	phi(grados)
t(s) = 12.200	v(m/s) = 0.233	w(rad/s) = 0.420	x(m) = 0.303	y(m) = 1.645	phi(grados)
t(s) = 12.300	v(m/s) = 0.238	w(rad/s) = 0.406	x(m) = 0.280	y(m) = 1.640	phi(grados)
t(s) = 12.400	v(m/s) = 0.243	w(rad/s) = 0.392	x(m) = 0.257	y(m) = 1.633	phi(grados)
t(s) = 12.500	v(m/s) = 0.247	w(rad/s) = 0.378	x(m) = 0.234	y(m) = 1.626	phi(grados)
t(s) = 12.600	v(m/s) = 0.252	w(rad/s) = 0.363	x(m) = 0.210	y(m) = 1.618	phi(grados)
t(s) = 12.700	v(m/s) = 0.257	w(rad/s) = 0.349	x(m) = 0.187	y(m) = 1.609	phi(grados)
t(s) = 12.800	v(m/s) = 0.261	w(rad/s) = 0.335	x(m) = 0.164	y(m) = 1.598	phi(grados)
t(s) = 12.900	v(m/s) = 0.266	w(rad/s) = 0.321	x(m) = 0.140	y(m) = 1.587	phi(grados)
t(s) = 13.000	v(m/s) = 0.270	w(rad/s) = 0.307	x(m) = 0.116	y(m) = 1.575	phi(grados)
t(s) = 13.100	v(m/s) = 0.274	w(rad/s) = 0.300	x(m) = 0.093	y(m) = 1.562	phi(grados)
t(s) = 13.200	v(m/s) = 0.277	w(rad/s) = 0.294	x(m) = 0.069	y(m) = 1.548	phi(grados)
t(s) = 13.300	v(m/s) = 0.280	w(rad/s) = 0.287	x(m) = 0.046	y(m) = 1.533	phi(grados)
t(s) = 13.400	v(m/s) = 0.283	w(rad/s) = 0.281	x(m) = 0.023	y(m) = 1.517	phi(grados)
t(s) = 13.500	v(m/s) = 0.287	w(rad/s) = 0.274	x(m) = -0.000	y(m) = 1.501	phi(grados)
t(s) = 13.600	v(m/s) = 0.290	w(rad/s) = 0.268	x(m) = -0.023	y(m) = 1.483	phi(grados)
t(s) = 13.700	v(m/s) = 0.293	w(rad/s) = 0.262	x(m) = -0.046	y(m) = 1.465	phi(grados)
t(s) = 13.800	v(m/s) = 0.296	w(rad/s) = 0.255	x(m) = -0.068	y(m) = 1.446	phi(grados)
t(s) = 13.900	v(m/s) = 0.299	w(rad/s) = 0.249	x(m) = -0.090	y(m) = 1.426	phi(grados)
t(s) = 14.000	v(m/s) = 0.303	w(rad/s) = 0.242	x(m) = -0.112	y(m) = 1.406	phi(grados)
t(s) = 14.100	v(m/s) = 0.304	w(rad/s) = 0.240	x(m) = -0.133	y(m) = 1.384	phi(grados)
t(s) = 14.200	v(m/s) = 0.305	w(rad/s) = 0.238	x(m) = -0.154	y(m) = 1.363	phi(grados)
t(s) = 14.300	v(m/s) = 0.306	w(rad/s) = 0.237	x(m) = -0.175	y(m) = 1.340	phi(grados)
t(s) = 14.400	v(m/s) = 0.307	w(rad/s) = 0.235	x(m) = -0.195	y(m) = 1.317	phi(grados)
t(s) = 14.500	v(m/s) = 0.308	w(rad/s) = 0.233	x(m) = -0.215	y(m) = 1.294	phi(grados)
t(s) = 14.600	v(m/s) = 0.310	w(rad/s) = 0.231	x(m) = -0.234	y(m) = 1.269	phi(grados)
t(s) = 14.700	v(m/s) = 0.311	w(rad/s) = 0.229	x(m) = -0.253	y(m) = 1.245	phi(grados)
t(s) = 14.800	v(m/s) = 0.312	w(rad/s) = 0.227	x(m) = -0.271	y(m) = 1.220	phi(grados)
t(s) = 14.900	v(m/s) = 0.313	w(rad/s) = 0.225	x(m) = -0.289	y(m) = 1.194	phi(grados)
t(s) = 15.000	v(m/s) = 0.314	w(rad/s) = 0.224	x(m) = -0.306	y(m) = 1.168	phi(grados)
t(s) = 15.100	v(m/s) = 0.313	w(rad/s) = 0.225	x(m) = -0.323	y(m) = 1.141	phi(grados)
t(s) = 15.200	v(m/s) = 0.312	w(rad/s) = 0.227	x(m) = -0.339	y(m) = 1.114	phi(grados)
t(s) = 15.300	v(m/s) = 0.311	w(rad/s) = 0.229	x(m) = -0.354	y(m) = 1.087	phi(grados)
t(s) = 15.400	v(m/s) = 0.310	w(rad/s) = 0.231	x(m) = -0.369	y(m) = 1.060	phi(grados)
t(s) = 15.500	v(m/s) = 0.308	w(rad/s) = 0.233	x(m) = -0.383	y(m) = 1.032	phi(grados)
t(s) = 15.600	v(m/s) = 0.307	w(rad/s) = 0.235	x(m) = -0.396	y(m) = 1.004	phi(grados)
t(s) = 15.700	v(m/s) = 0.306	w(rad/s) = 0.237	x(m) = -0.409	y(m) = 0.976	phi(grados)
t(s) = 15.800	v(m/s) = 0.305	w(rad/s) = 0.238	x(m) = -0.421	y(m) = 0.948	phi(grados)
t(s) = 15.900	v(m/s) = 0.304	w(rad/s) = 0.240	x(m) = -0.432	y(m) = 0.920	phi(grados)
t(s) = 16.000	v(m/s) = 0.303	w(rad/s) = 0.242	x(m) = -0.442	y(m) = 0.891	phi(grados)
t(s) = 16.100	v(m/s) = 0.299	w(rad/s) = 0.249	x(m) = -0.452	y(m) = 0.862	phi(grados)
t(s) = 16.200	v(m/s) = 0.296	w(rad/s) = 0.255	x(m) = -0.461	y(m) = 0.834	phi(grados)
t(s) = 16.300	v(m/s) = 0.293	w(rad/s) = 0.262	x(m) = -0.469	y(m) = 0.805	phi(grados)
t(s) = 16.400	v(m/s) = 0.290	w(rad/s) = 0.268	x(m) = -0.476	y(m) = 0.777	phi(grados)
t(s) = 16.500	v(m/s) = 0.287	w(rad/s) = 0.274	x(m) = -0.482	y(m) = 0.749	phi(grados)
t(s) = 16.600	v(m/s) = 0.283	w(rad/s) = 0.281	x(m) = -0.488	y(m) = 0.721	phi(grados)
t(s) = 16.700	v(m/s) = 0.280	w(rad/s) = 0.287	x(m) = -0.493	y(m) = 0.693	phi(grados)
t(s) = 16.800	v(m/s) = 0.277	w(rad/s) = 0.294	x(m) = -0.497	y(m) = 0.665	phi(grados)

```
t(s) = 16.900     | v(m/s) = 0.274     | w(rad/s) = 0.300     | x(m) = -0.500     | y(m) = 0.637     phi(grados)
t(s) = 17.000     | v(m/s) = 0.270     | w(rad/s) = 0.307     | x(m) = -0.502     | y(m) = 0.610     phi(grados)
t(s) = 17.100     | v(m/s) = 0.266     | w(rad/s) = 0.321     | x(m) = -0.503     | y(m) = 0.583     phi(grados)
t(s) = 17.200     | v(m/s) = 0.261     | w(rad/s) = 0.335     | x(m) = -0.503     | y(m) = 0.557     phi(grados)
t(s) = 17.300     | v(m/s) = 0.257     | w(rad/s) = 0.349     | x(m) = -0.503     | y(m) = 0.530     phi(grados)
t(s) = 17.400     | v(m/s) = 0.252     | w(rad/s) = 0.363     | x(m) = -0.502     | y(m) = 0.505     phi(grados)
t(s) = 17.500     | v(m/s) = 0.247     | w(rad/s) = 0.378     | x(m) = -0.499     | y(m) = 0.480     phi(grados)
t(s) = 17.600     | v(m/s) = 0.243     | w(rad/s) = 0.392     | x(m) = -0.496     | y(m) = 0.455     phi(grados)
t(s) = 17.700     | v(m/s) = 0.238     | w(rad/s) = 0.406     | x(m) = -0.492     | y(m) = 0.431     phi(grados)
t(s) = 17.800     | v(m/s) = 0.233     | w(rad/s) = 0.420     | x(m) = -0.487     | y(m) = 0.408     phi(grados)
t(s) = 17.900     | v(m/s) = 0.229     | w(rad/s) = 0.434     | x(m) = -0.482     | y(m) = 0.385     phi(grados)
t(s) = 18.000     | v(m/s) = 0.224     | w(rad/s) = 0.449     | x(m) = -0.475     | y(m) = 0.363     phi(grados)
t(s) = 18.100     | v(m/s) = 0.220     | w(rad/s) = 0.471     | x(m) = -0.468     | y(m) = 0.342     phi(grados)
t(s) = 18.200     | v(m/s) = 0.215     | w(rad/s) = 0.493     | x(m) = -0.459     | y(m) = 0.322     phi(grados)
t(s) = 18.300     | v(m/s) = 0.210     | w(rad/s) = 0.516     | x(m) = -0.450     | y(m) = 0.302     phi(grados)
t(s) = 18.400     | v(m/s) = 0.206     | w(rad/s) = 0.538     | x(m) = -0.441     | y(m) = 0.284     phi(grados)
t(s) = 18.500     | v(m/s) = 0.201     | w(rad/s) = 0.560     | x(m) = -0.430     | y(m) = 0.266     phi(grados)
t(s) = 18.600     | v(m/s) = 0.197     | w(rad/s) = 0.583     | x(m) = -0.419     | y(m) = 0.249     phi(grados)
t(s) = 18.700     | v(m/s) = 0.192     | w(rad/s) = 0.605     | x(m) = -0.407     | y(m) = 0.234     phi(grados)
t(s) = 18.800     | v(m/s) = 0.187     | w(rad/s) = 0.628     | x(m) = -0.394     | y(m) = 0.219     phi(grados)
t(s) = 18.900     | v(m/s) = 0.183     | w(rad/s) = 0.650     | x(m) = -0.381     | y(m) = 0.206     phi(grados)
t(s) = 19.000     | v(m/s) = 0.178     | w(rad/s) = 0.672     | x(m) = -0.368     | y(m) = 0.194     phi(grados)
t(s) = 19.100     | v(m/s) = 0.176     | w(rad/s) = 0.685     | x(m) = -0.354     | y(m) = 0.183     phi(grados)
t(s) = 19.200     | v(m/s) = 0.174     | w(rad/s) = 0.698     | x(m) = -0.339     | y(m) = 0.173     phi(grados)
t(s) = 19.300     | v(m/s) = 0.172     | w(rad/s) = 0.711     | x(m) = -0.324     | y(m) = 0.164     phi(grados)
t(s) = 19.400     | v(m/s) = 0.170     | w(rad/s) = 0.723     | x(m) = -0.308     | y(m) = 0.157     phi(grados)
t(s) = 19.500     | v(m/s) = 0.168     | w(rad/s) = 0.736     | x(m) = -0.293     | y(m) = 0.150     phi(grados)
t(s) = 19.600     | v(m/s) = 0.166     | w(rad/s) = 0.749     | x(m) = -0.277     | y(m) = 0.145     phi(grados)
t(s) = 19.700     | v(m/s) = 0.163     | w(rad/s) = 0.762     | x(m) = -0.261     | y(m) = 0.141     phi(grados)
t(s) = 19.800     | v(m/s) = 0.161     | w(rad/s) = 0.775     | x(m) = -0.244     | y(m) = 0.139     phi(grados)
t(s) = 19.900     | v(m/s) = 0.159     | w(rad/s) = 0.787     | x(m) = -0.228     | y(m) = 0.138     phi(grados)
t(s) = 20.000     | v(m/s) = 0.157     | w(rad/s) = 0.800     | x(m) = -0.212     | y(m) = 0.138     phi(grados)
```

Simulación 3D

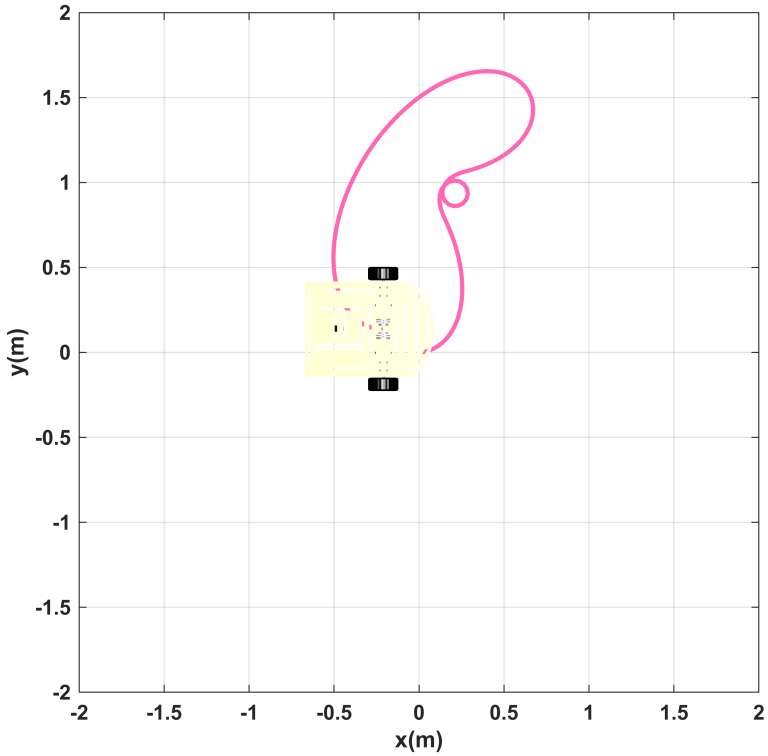
Se configura una escena en 3D donde se observa el movimiento del robot en el plano XY. Se utiliza una figura gráfica que se actualiza en cada iteración del bucle para animar la trayectoria del robot.

```
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([-2 2 -2 2 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
```

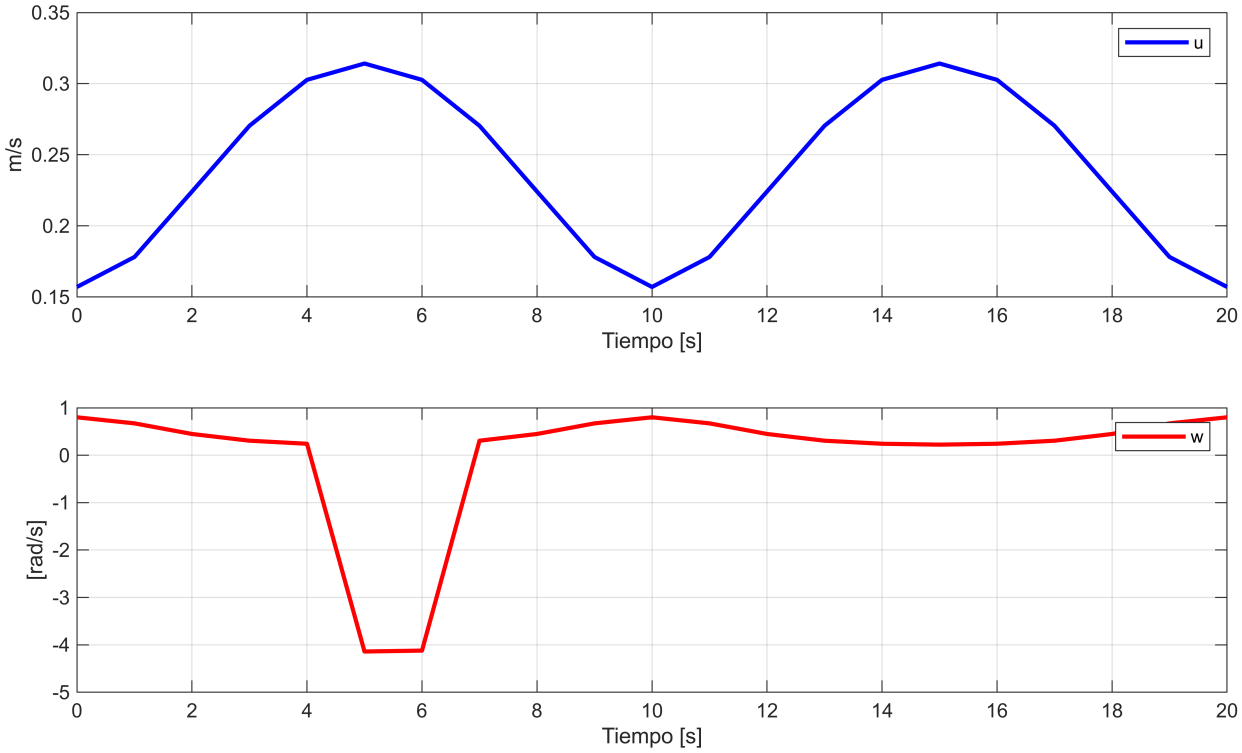


Gráficas

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');
```

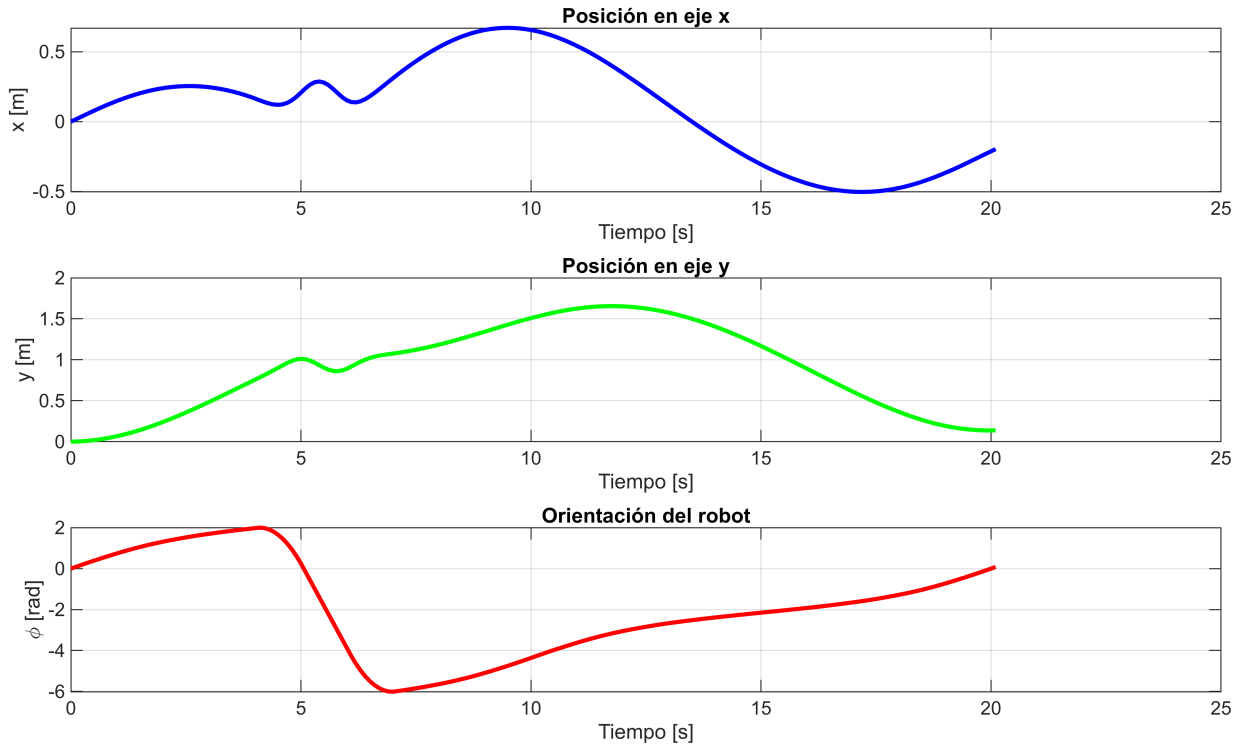



```
figure;
set(gcf,'position',sizeScreen);

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 = 15*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) = -15;
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 = 301.80 rad/s | ω_L = 298.20 rad/s
t = 0.02 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
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t = 5.24 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.25 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.26 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.27 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.28 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.29 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.30 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.31 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.32 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.33 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.34 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.35 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.36 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.37 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.38 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.39 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.40 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.41 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.42 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.43 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.44 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.45 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.46 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.47 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.48 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.49 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.50 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.51 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.52 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.53 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.54 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.55 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.56 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.57 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.58 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.59 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.60 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.61 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.62 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.63 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.64 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.65 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.66 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.67 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.68 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s

t = 5.69 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.70 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.71 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.72 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.73 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.74 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.75 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.76 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.77 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.78 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.79 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.80 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.81 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.82 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.83 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.84 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.85 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.86 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.87 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.88 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.89 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.90 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.91 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.92 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.93 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.94 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.95 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.96 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.97 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.98 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 5.99 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 6.00 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 6.01 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 6.02 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 6.03 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 6.04 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 6.05 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 6.06 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 6.07 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 6.08 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 6.09 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 6.10 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 6.11 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 6.12 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 6.13 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 6.14 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 6.15 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 6.16 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 6.17 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 6.18 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 6.19 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 6.20 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 6.21 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 6.22 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 6.23 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 6.24 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 6.25 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 6.26 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 6.27 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 6.28 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 6.29 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 6.30 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 6.31 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 6.32 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s

```
t = 6.33 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 6.34 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 6.35 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 6.36 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 6.37 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 6.38 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 6.39 s | ω_R = 301.80 rad/s | ω_L = 298.20 rad/s
t = 6.40 s | ω_R = 301.80 rad/s | ω_L = 298.20 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
```

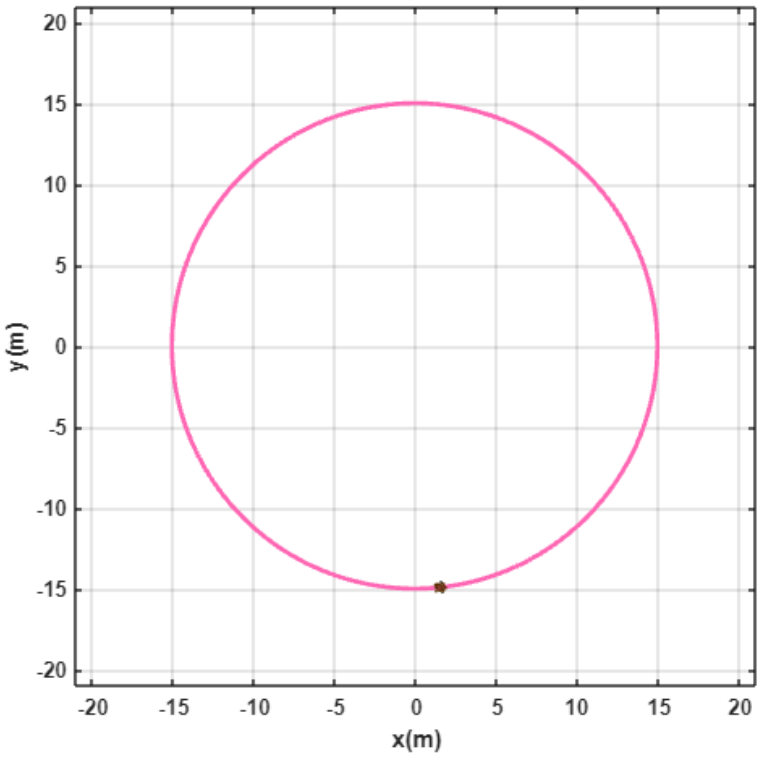
```
for k=1:step:N

    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;
```