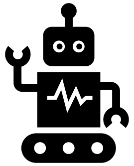
Robots Moviles



UNIDAD 4 Y UNIDAD 5: Introducción al control y Navegación

Dra. Carolina Díaz Baca

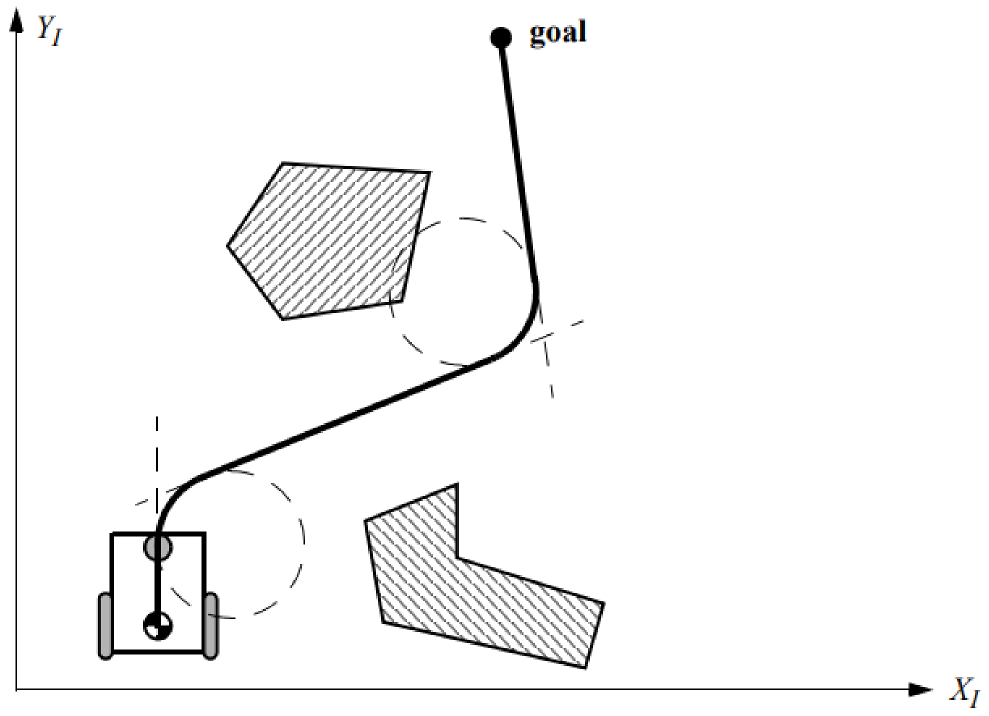
Unidad 4 y Unidad 5 (A)
introduccion al control Y Navegación

Lazo abierto / lazo cerrado

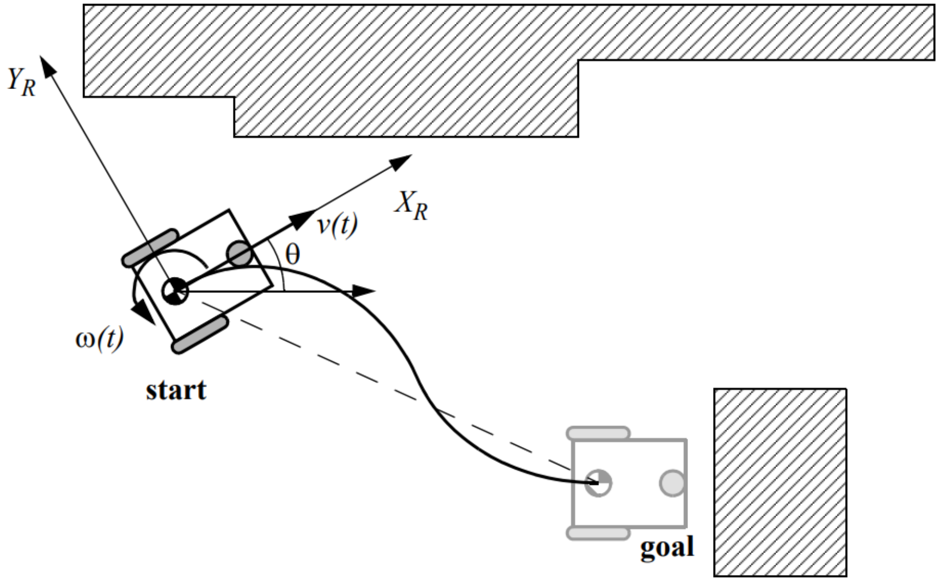
Sistemas hibridos

Otros

Control de Movimiento

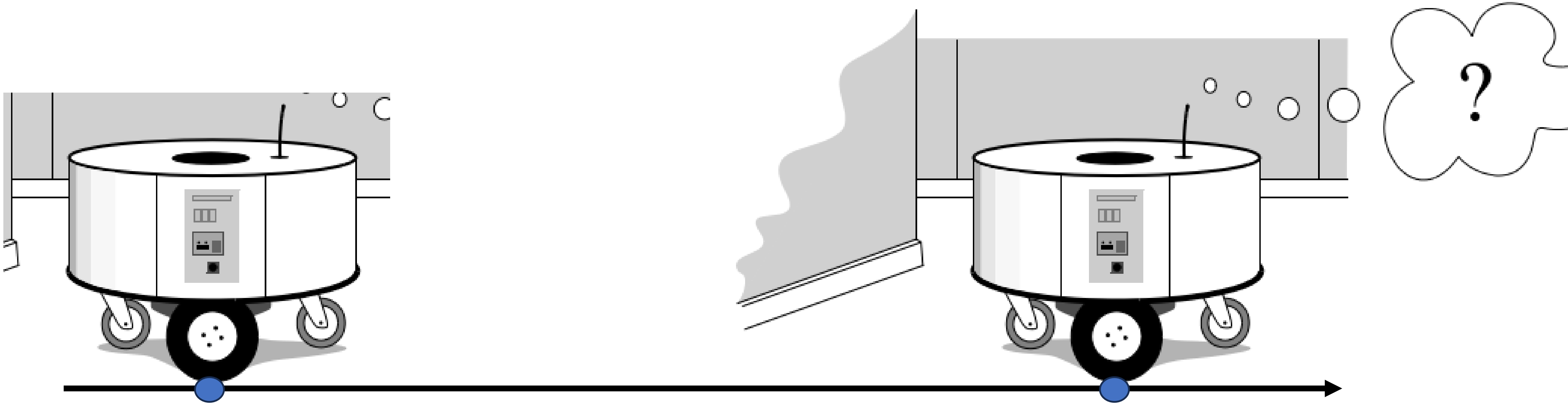


Control por trayectorias

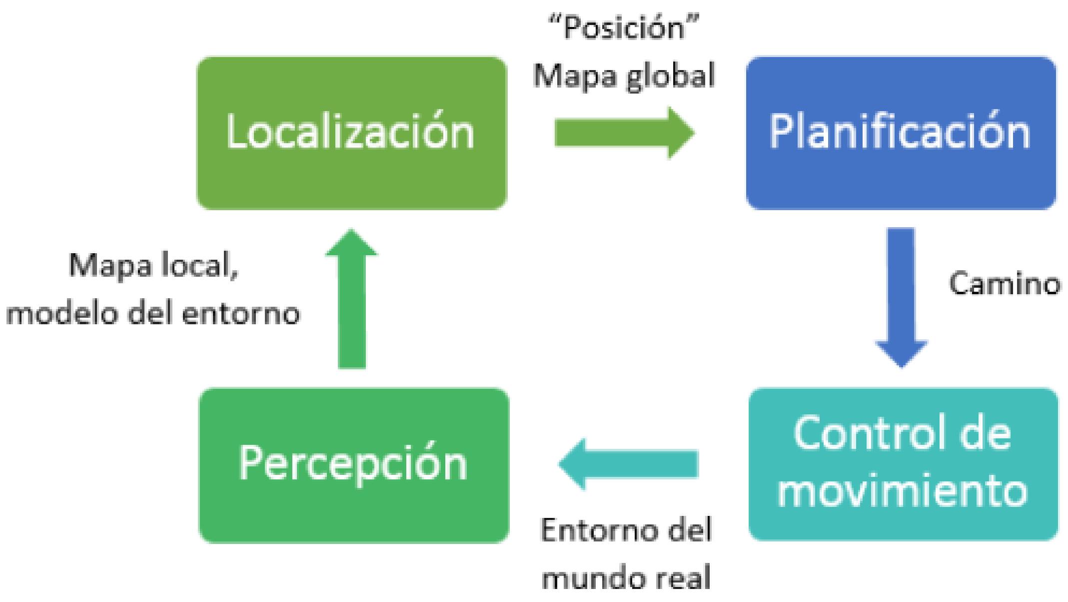


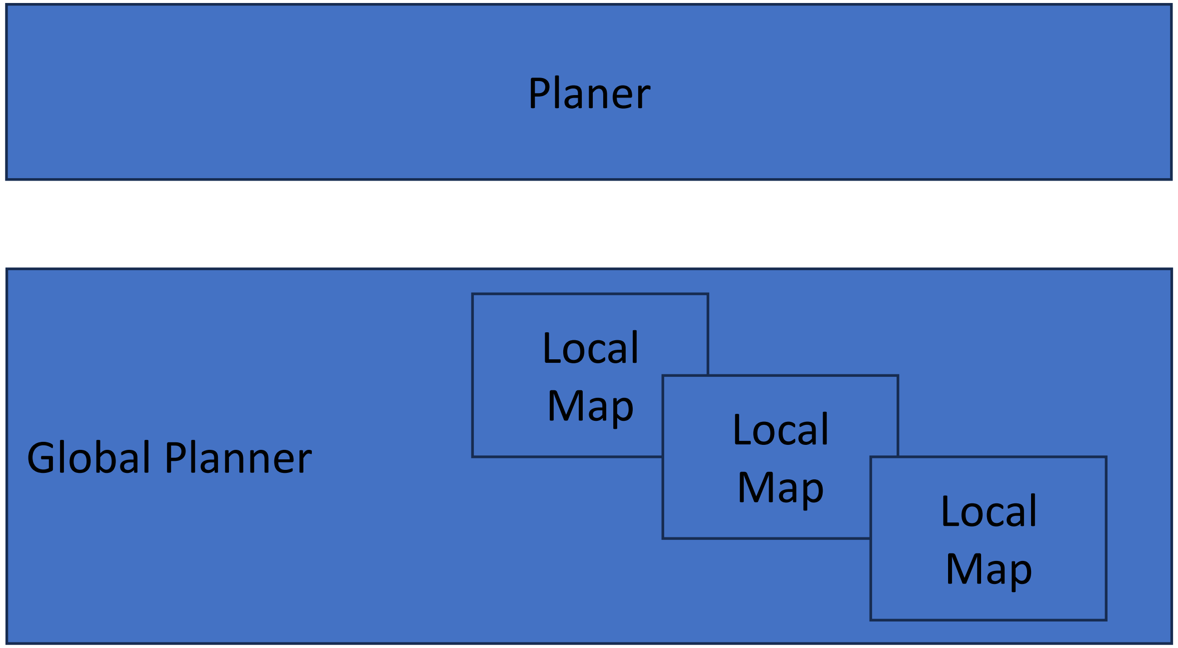
Control posición y velocidad

La **odometría** es el estudio de la estimación de la posición de vehículos con ruedas durante la navegación. Para realizar esta estimación se usa información sobre la rotación de las ruedas para estimar cambios en la posición a lo largo del tiempo. Este término también se usa a veces para referirse a la distancia que ha recorrido uno de estos vehículos (pudiéndose emplear otros sensores para su cálculo, como la odometría visual).



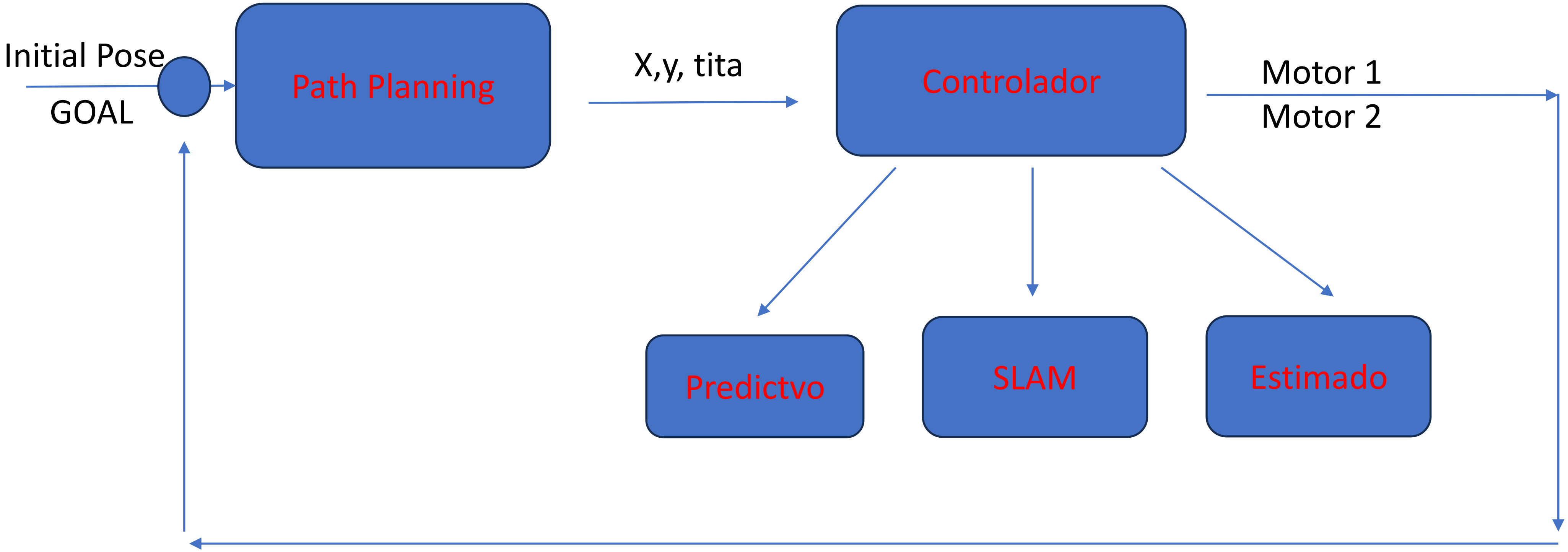
Sensores propioceptivos (encoders) + senrores exteroceptivos (Lidar)





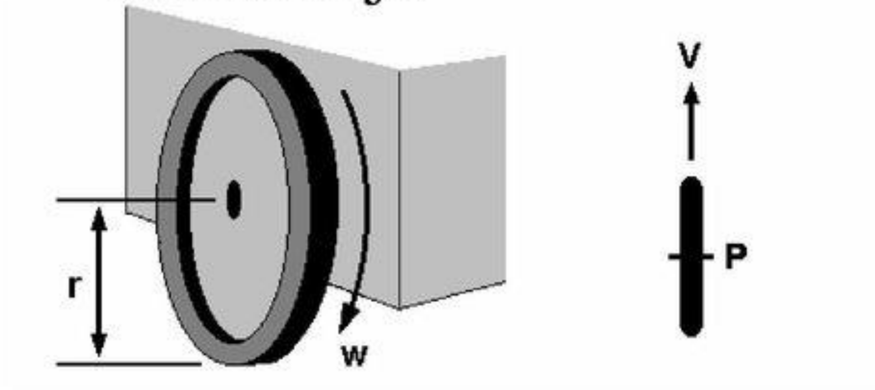
- Obstaculos dinamicos se actualizan antes en el LM
- Funcionan a la par yo puedo decidir quien manda en funcion del ambiente

Navigation Module

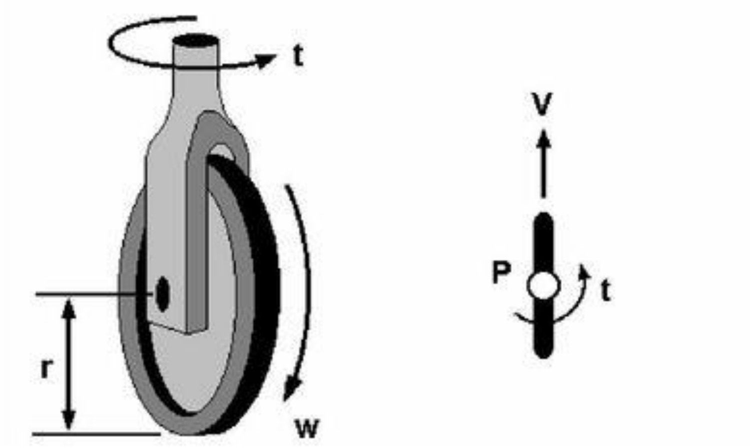


Algunos conceptos previos

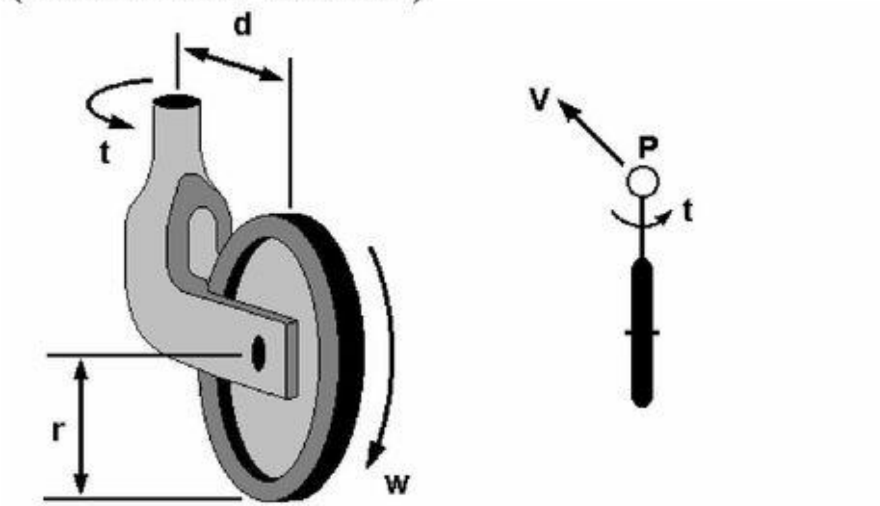
Rueda Fija



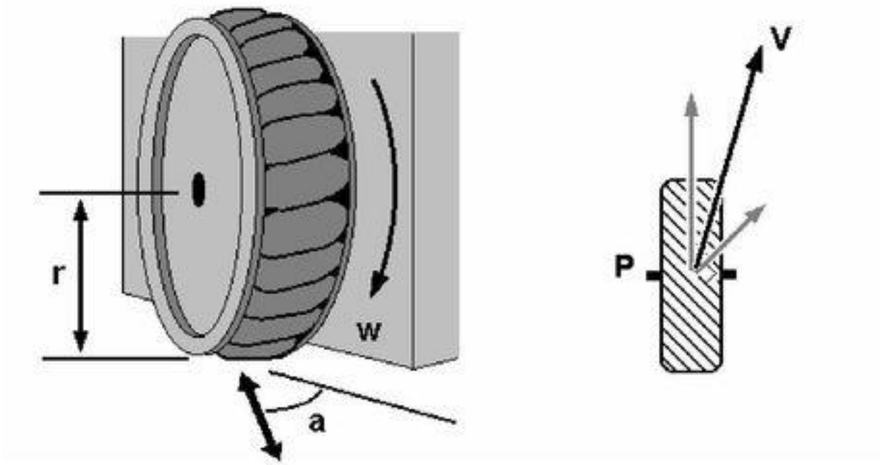
Rueda orientable centrada

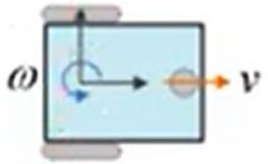


Rueda orientable descentrada
(Rueda de Castor)



Ruedas Suecas: Ruedas omnidireccionales





- Cinemática directa:

$$^{R}\dot{\xi} = A^{\#} B \dot{\varphi}$$

$$^{R}\begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{\theta} \end{bmatrix} = \begin{bmatrix} \frac{r}{2} & \frac{r}{2} \\ 0 & 0 \\ \frac{r}{2b} & -\frac{r}{2b} \end{bmatrix} \begin{bmatrix} \dot{\varphi}_d \\ \dot{\varphi}_i \end{bmatrix}$$

⇨

$$^{R}\dot{x} = v = \frac{r}{2}\left(\dot{\varphi}_d + \dot{\varphi}_i\right)$$

$$\dot{\theta} = \omega = \frac{r}{2b}\left(\dot{\varphi}_d - \dot{\varphi}_i\right)$$

Nota: v, ω en el sistema del robot

- Cinemática inversa:

$$\dot{\varphi} = B^{\#} A \, ^{R}\dot{\xi}$$

$$\begin{bmatrix} \dot{\varphi}_d \\ \dot{\varphi}_i \end{bmatrix} = \begin{bmatrix} 1/r & 0 & b/r \\ 1/r & 0 & -b/r \end{bmatrix} {}^{R}\begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{\theta} \end{bmatrix}$$

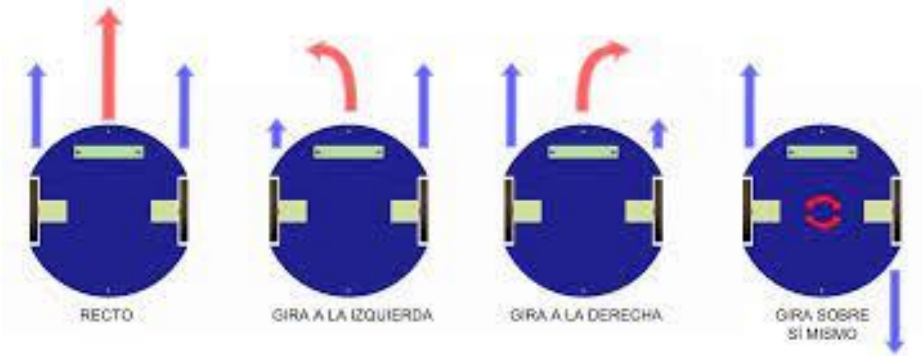
⇨

$$\dot{\varphi}_d = \frac{1}{r}\left(v + b\omega\right)$$

$$\dot{\varphi}_i = \frac{1}{r}\left(v - b\omega\right)$$

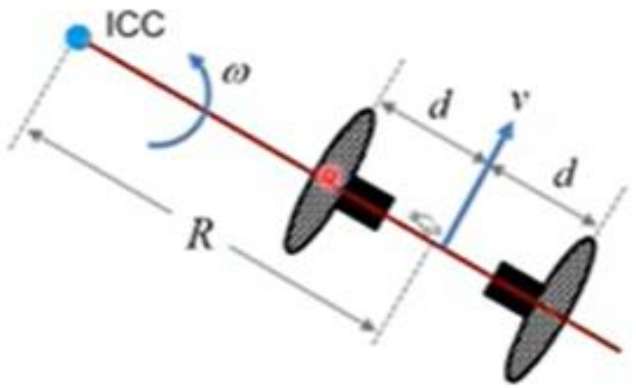
$$v = {}^{R}\dot{x}$$

$$\omega = \dot{\theta}$$



Maniobrabilidad y Restricciones

El movimiento de un robot diferencial puede ser representado como una rotación alrededor de un punto, el cual se denomina ICC (*Instantaneous Curvature Center*), como se muestra en la siguiente figura. Determinar el radio de giro R en función de la velocidad de las ruedas del robot.

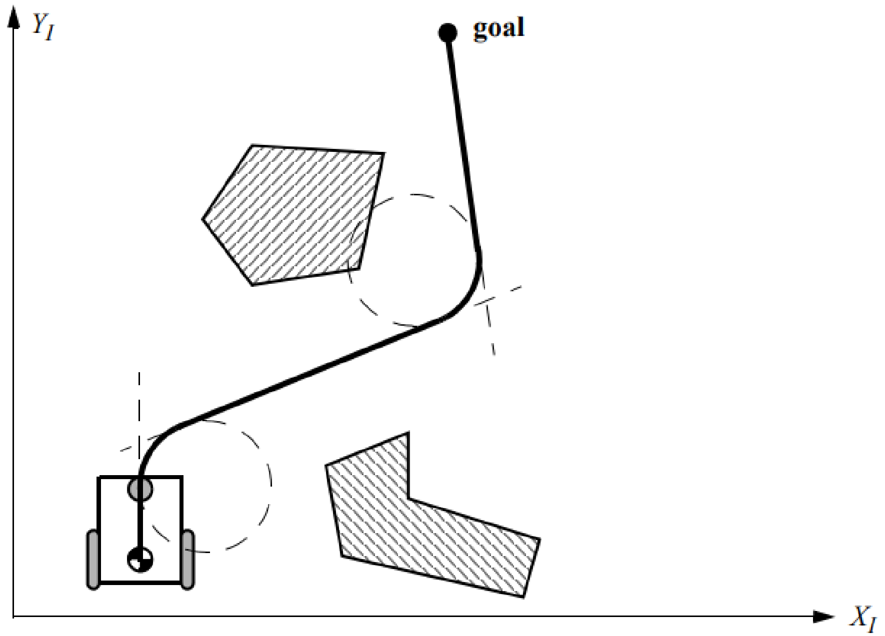


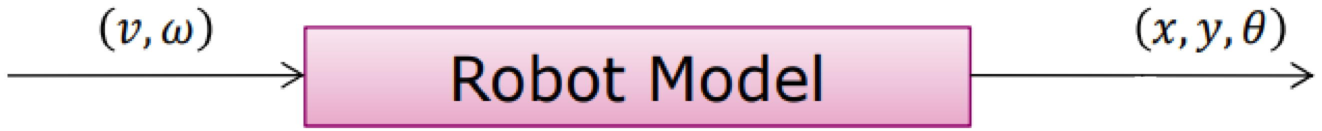
Solución

- La relación entre velocidad lineal y angular está dada por $v = \omega R$.
- Se reescribe la relación como:

$$R = \frac{v}{\omega} = \frac{b(\dot{\varphi}_d + \dot{\varphi}_i)}{\dot{\varphi}_d - \dot{\varphi}_i}$$

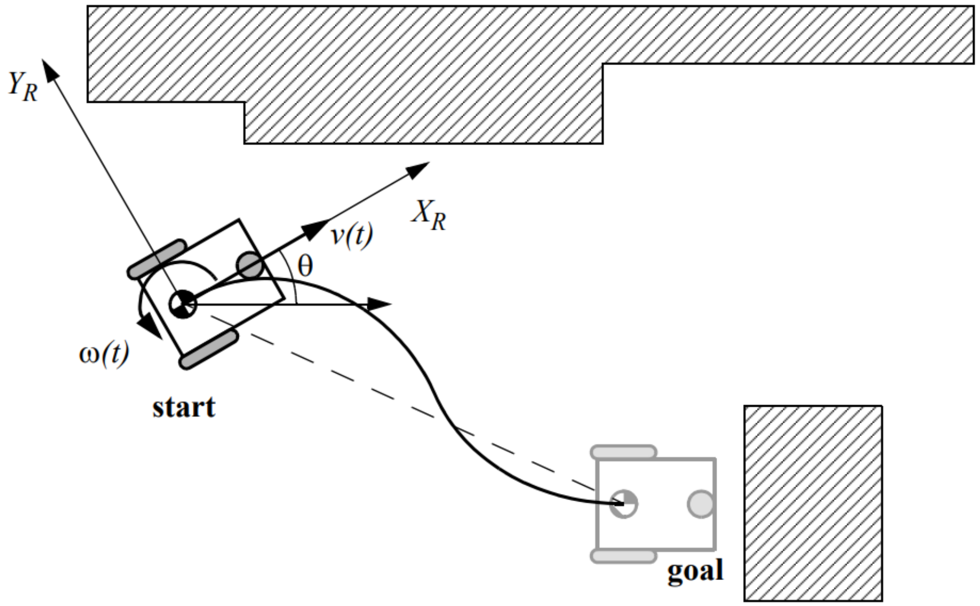
Control de Movimiento: Lazo abierto



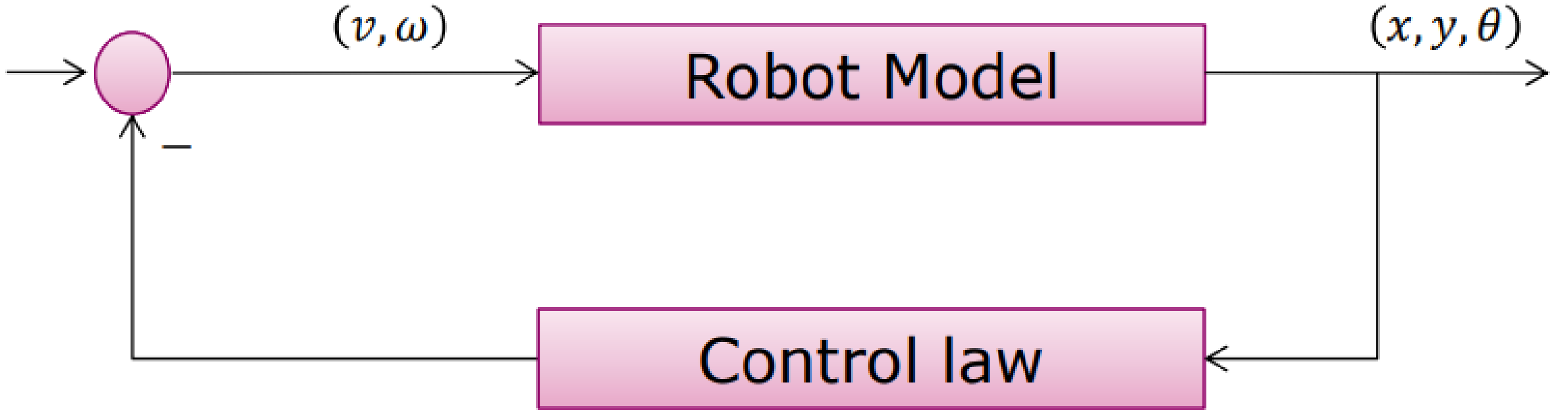


- No se relimenta posición no se concideran cambios bruscon en la aceleracion
- El robot no se adaptara a cambios dinamicos que puedan ocurrir en el entorno
- Dificultades del y dinamica del terreno no llegara a la meta

Control de Movimiento: Lazo cerrado

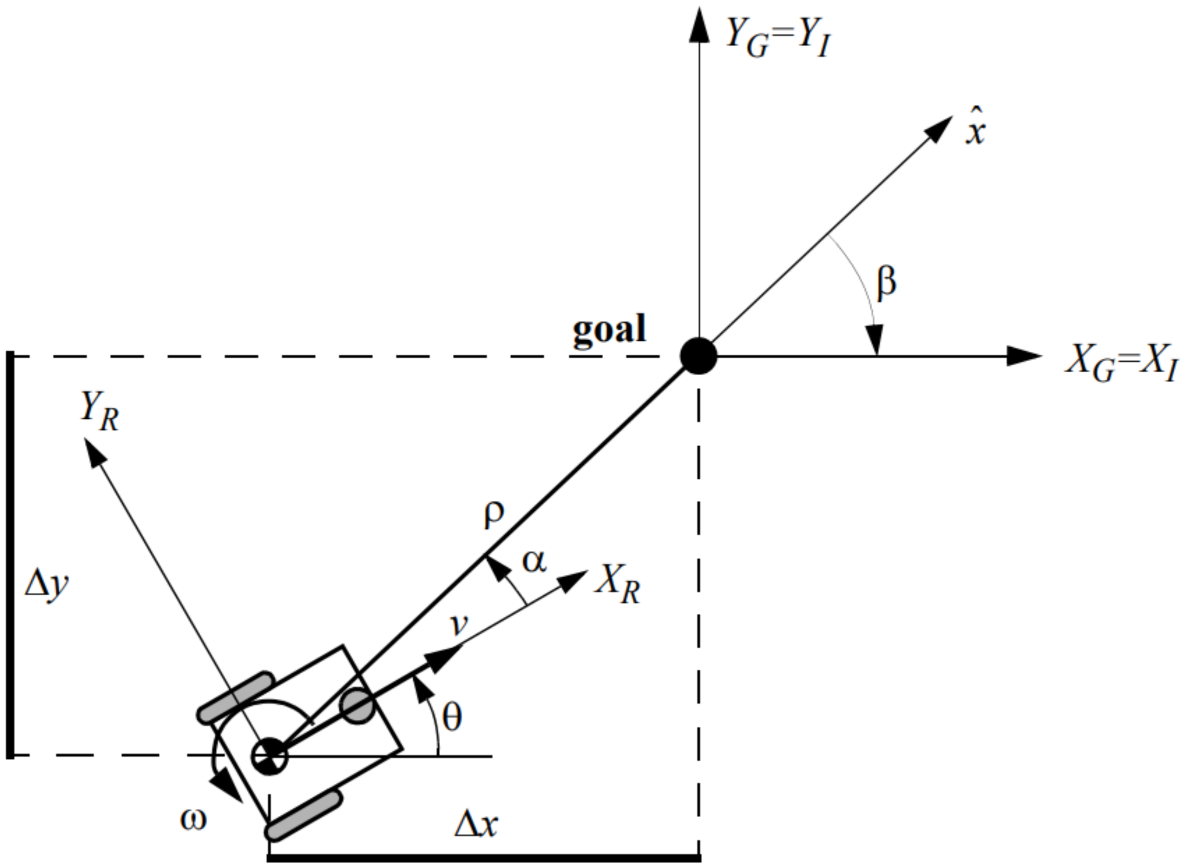


$$\lim_{t \to \infty} e(t) = 0 .$$



- Llevar ese error a cero minimiaer el error en posicion y orientacion MIMO (Multiples input and outputs)
- State feedback control

Control de Movimiento: Lazo cerrado



$$K = \begin{bmatrix} k_{11} & k_{12} & k_{13} \\ k_{21} & k_{22} & k_{23} \end{bmatrix} \qquad \text{with } k_{ij} = k(t, e),$$

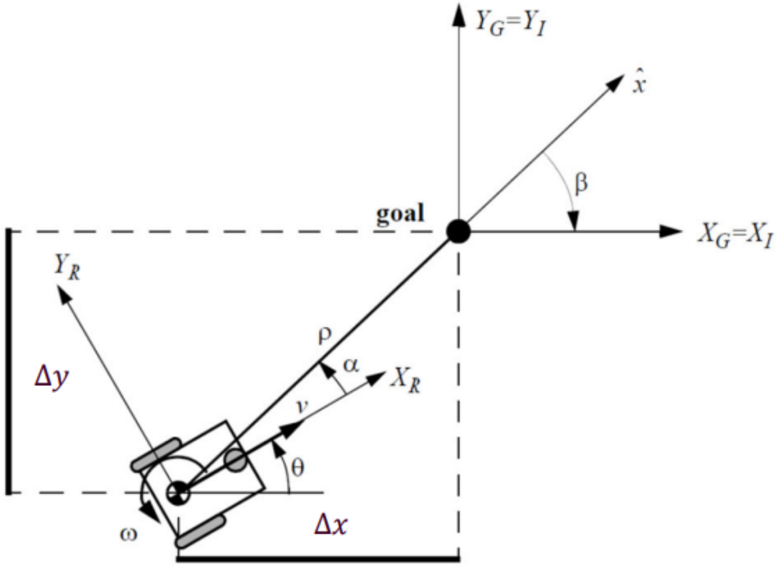
$$\begin{bmatrix} v(t) \\ \omega(t) \end{bmatrix} = K \cdot e = K \, {}^R\begin{bmatrix} x \\ y \\ \theta \end{bmatrix}$$

$$\lim_{t \to \infty} e(t) = 0 .$$

Control de Movimiento: lazo cerrado

- The kinematics of a differential drive mobile robot described in the inertial frame $\{x_I, y_I, \theta\}$ is given by,

$$^{I}\begin{bmatrix}\dot{x}\\ \dot{y}\\ \dot{\theta}\end{bmatrix} = \begin{bmatrix}cos\theta & 0\\ sin\theta & 0\\ 0 & 1\end{bmatrix}\begin{bmatrix}v\\ \omega\end{bmatrix}$$



- where $\dot{x}$ and $\dot{y}$ are the linear velocities in the direction of the x_I and y_I of the inertial frame.
- Let α denote the angle between the x_R axis of the robot reference frame and the vector connecting the center of the axle of the wheels with the final position.

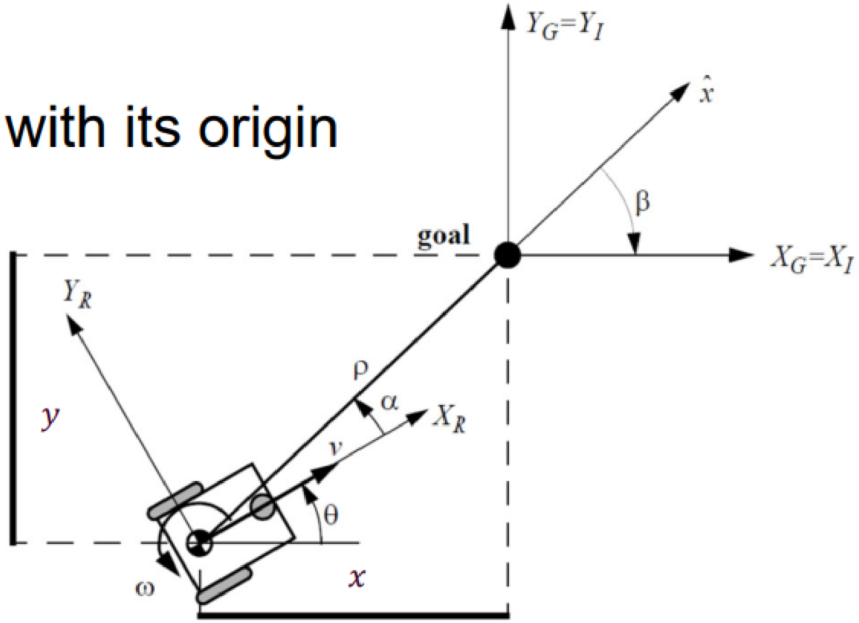
Control de Movimiento: lazo cerrado->coordenadas polares

- Coordinate transformation into polar coordinates with its origin at goal position:

$$\rho = \sqrt{\Delta x^2 + \Delta y^2}$$

$$\alpha = -\theta + \operatorname{atan2}(\Delta y, \Delta x)$$

$$\beta = -\theta - \alpha$$

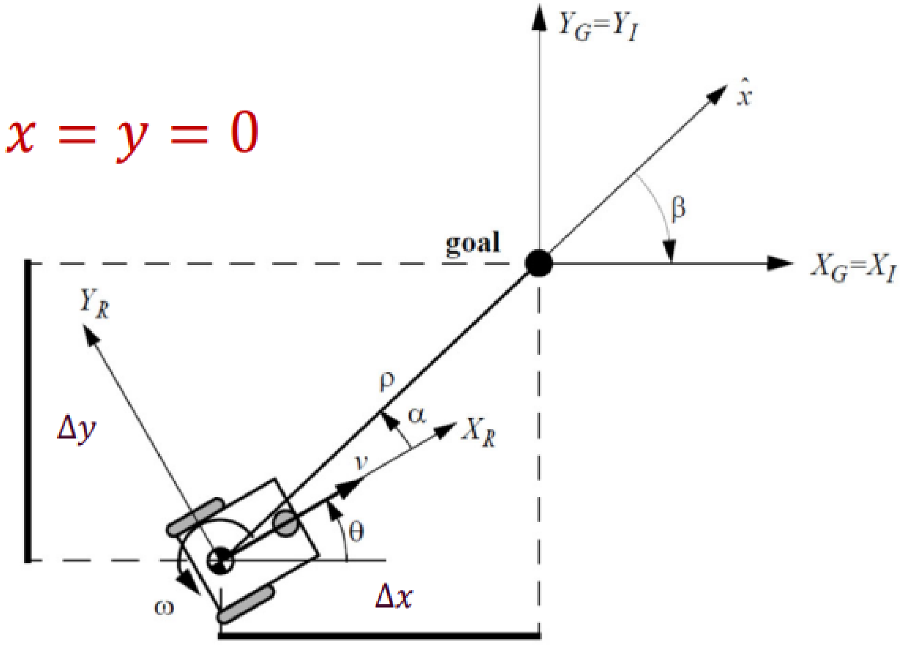


- System description, in the new polar coordinates

$$\begin{bmatrix} \dot\rho \\ \dot\alpha \\ \dot\beta \end{bmatrix} = \begin{bmatrix} -\cos\alpha & 0 \\ \frac{\sin\alpha}{\rho} & -1 \\ -\frac{\sin\alpha}{\rho} & 0 \end{bmatrix} \begin{bmatrix} v \\ \omega \end{bmatrix} \quad \text{and} \quad \begin{bmatrix} \dot\rho \\ \dot\alpha \\ \dot\beta \end{bmatrix} = \begin{bmatrix} \cos\alpha & 0 \\ -\frac{\sin\alpha}{\rho} & 1 \\ \frac{\sin\alpha}{\rho} & 0 \end{bmatrix} \begin{bmatrix} v \\ \omega \end{bmatrix}$$

for $\alpha \in I_1 = \left(-\frac{\pi}{2}, \frac{\pi}{2}\right]$ for $\alpha \in I_2 = \left(-\pi, -\frac{\pi}{2}\right] \cup \left(\frac{\pi}{2}, \pi\right]$ $\rightarrow v = -v$

Control de Movimiento: lazo cerrado->coordenadas polares



- The coordinates transformation is not defined at $x = y = 0$
  → Stop controller very close to the goal

- For $\alpha \in I_1$ the forward direction of the robot points toward the goal, for $\alpha \in I_2$ it is the backward direction.
  with $\alpha \in I_1 = \left(-\frac{\pi}{2}, \frac{\pi}{2}\right]$ and $\alpha \in I_2 = \left(-\pi, -\frac{\pi}{2}\right] \cup \left(\frac{\pi}{2}, \pi\right]$

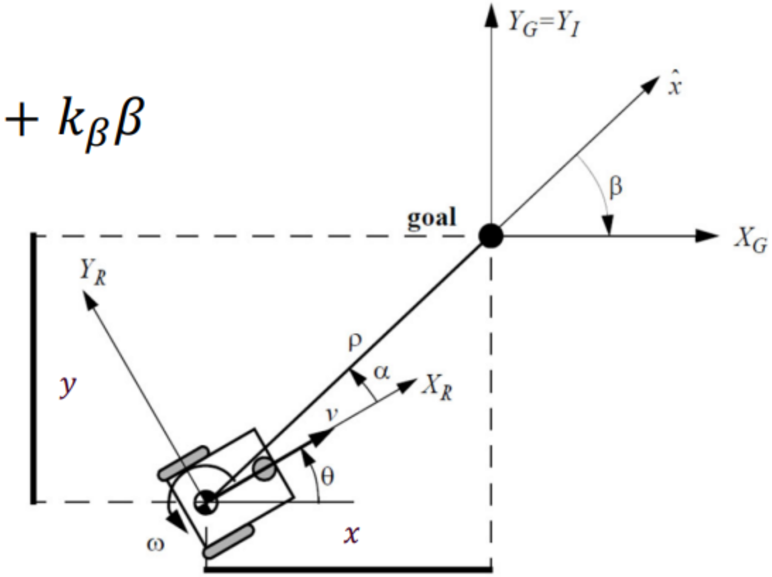
- By properly defining the forward direction of the robot at its initial configuration, it is always possible to have $\alpha \in I_1$ at $t = 0$. However, this does not mean that α remains in I_1 for all time t.

Control de Movimiento: Ley de Control

- It can be shown, that with $v = k_\rho \rho$ and $\omega = k_\alpha \alpha + k_\beta \beta$

  the feedback-controlled system

$$\begin{bmatrix} \dot{\rho} \\ \dot{\alpha} \\ \dot{\beta} \end{bmatrix} = \begin{bmatrix} -k_\rho \rho \cos \alpha \\ -k_\rho \sin \alpha - k_\alpha \alpha - k_\beta \beta \\ -k_\rho \sin \alpha \end{bmatrix}$$

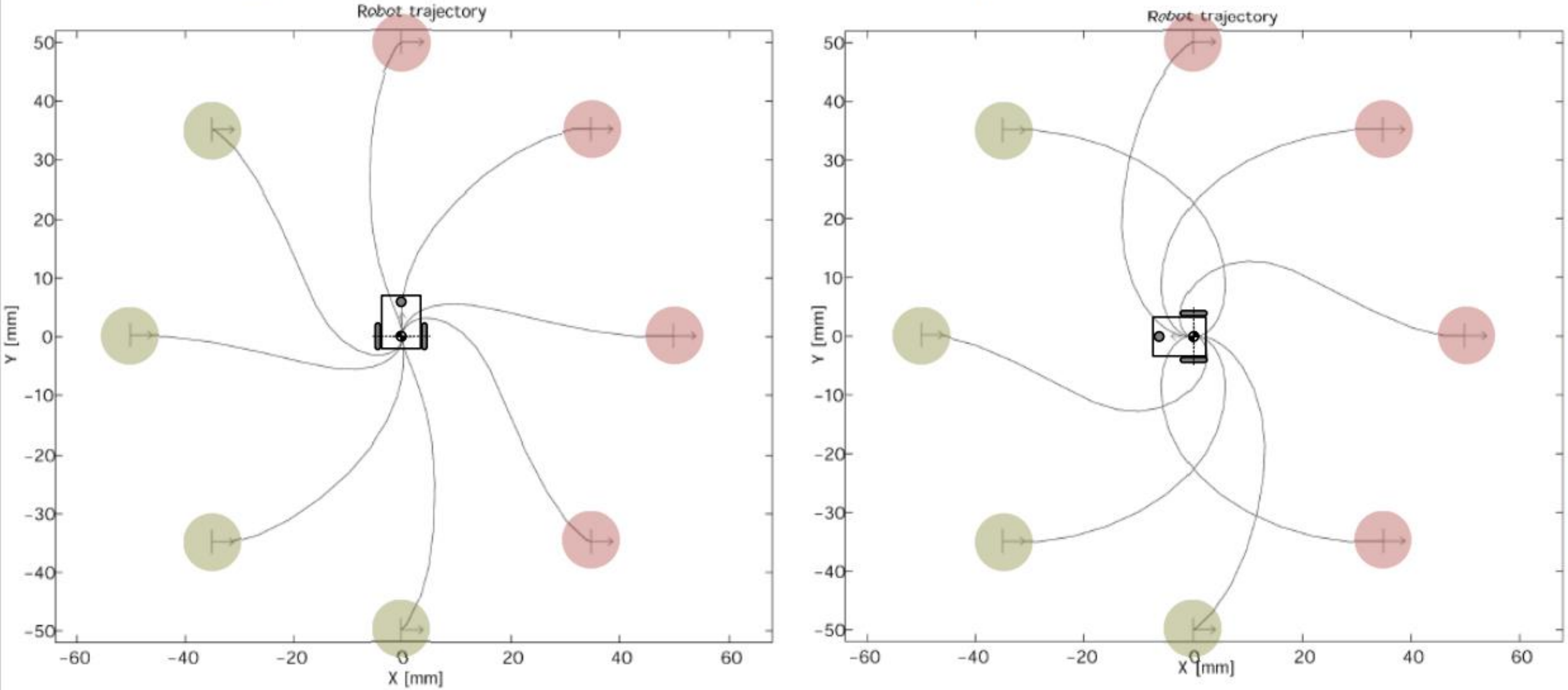


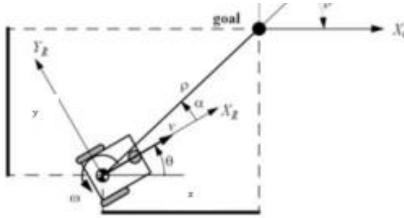
  will drive the robot to $(\rho, \alpha, \beta) = (0,0,0)$

- The control signal v has thereby always constant sign:
  - the direction of movement is kept positive or negative during movement
  - parking maneuver is performed always in the most natural way and without ever inverting its motion direction.

Control de Movimiento:

- The goal is in the center and the initial position on the circle.





$\boldsymbol{\alpha} \in \boldsymbol{I}_{1/2}$

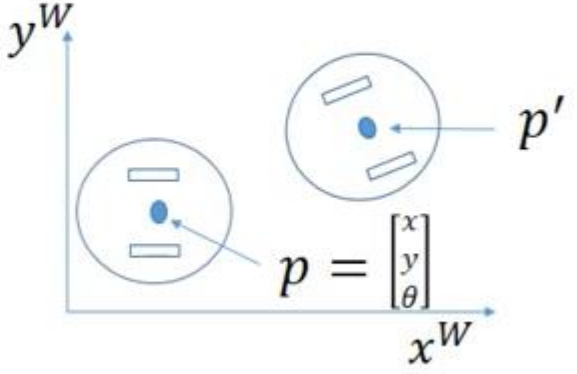
$I_1 = \left(-\frac{\pi}{2}, \frac{\pi}{2}\right]$
→ forward pointing to goal

$I_2 = \left(-\pi, -\frac{\pi}{2}\right] \cup \left(\frac{\pi}{2}, \pi\right]$
→ backward pointing to goal

$$k = (k_\rho, k_\alpha, k_\beta) = (3, 8, -1.5)$$

Control diferencial realimentado:

$$p' = \begin{bmatrix} x \\ y \\ \theta \end{bmatrix} + \begin{bmatrix} d\cos(\theta) \\ d\sin(\theta) \\ \Delta\theta \end{bmatrix}$$



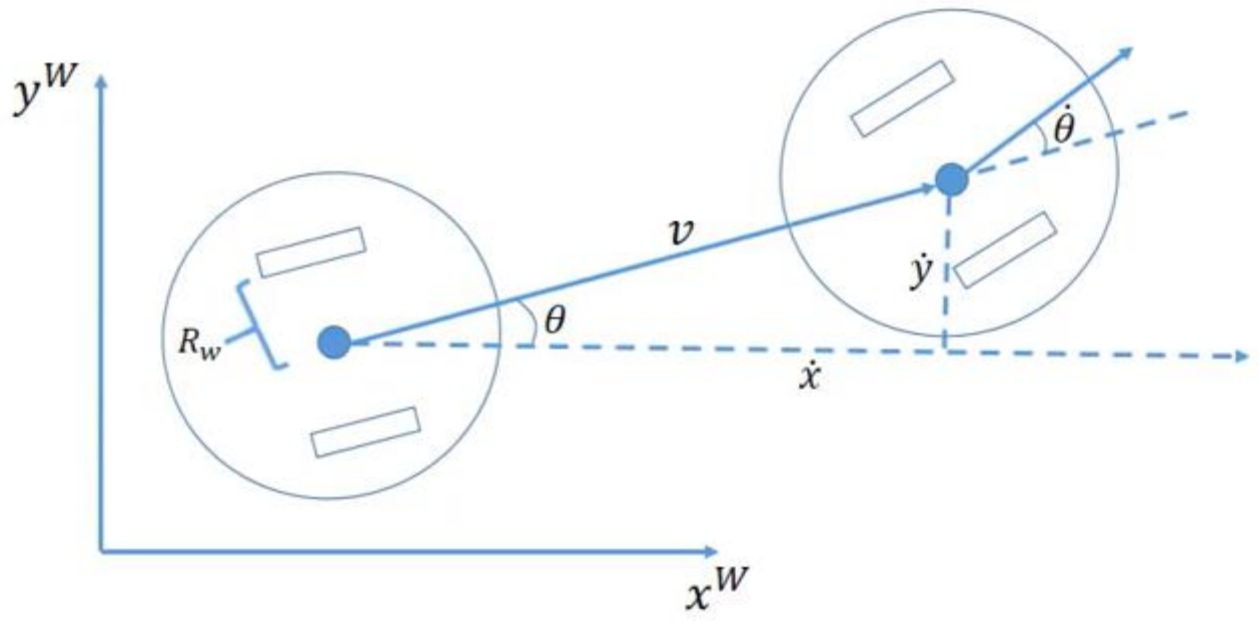
$$\Delta\theta = \frac{d_r - d_l}{2R_w}$$

$$d = \frac{d_l + d_r}{2}$$

$$\Delta x = d\cos(\theta)$$

$$\Delta y = d\sin(\theta)$$

Control diferencial realimentado:



$$\dot{x} = v\cos(\theta)$$
$$\dot{y} = v\,sin(\theta)$$

<u>Known:</u>

v_l = left wheel velocity
v_r = right wheel velocity
r = wheel radius

[No T

$$v = \frac{v_l + v_r}{2}$$

$$\dot{\theta} = \frac{r}{2R_w}(v_r - v_l)$$

Control diferencial realimentado:

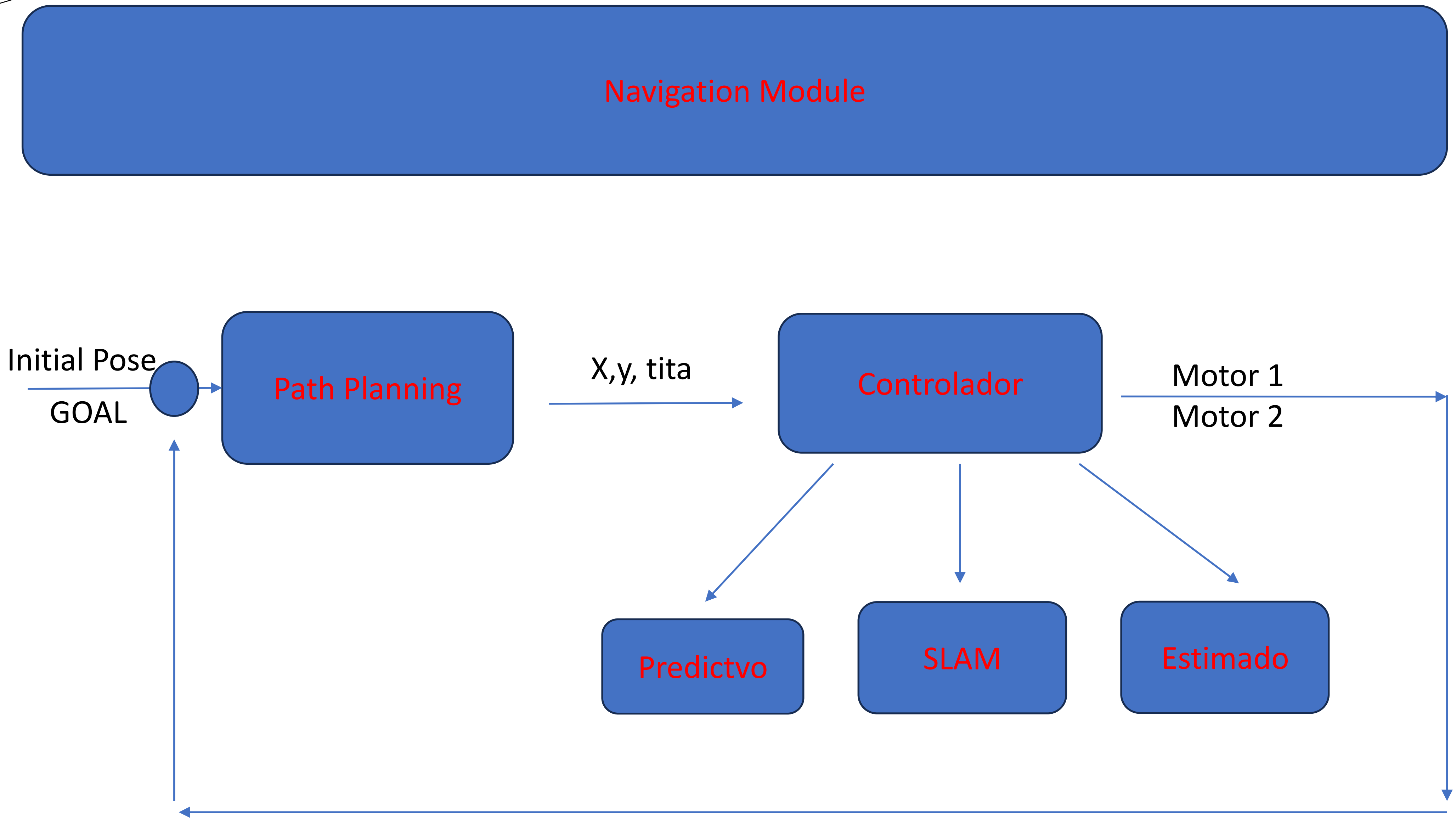
Control system:

$$\begin{bmatrix}\dot{x}\\ \dot{y}\\ \dot{\theta}\end{bmatrix} = \begin{bmatrix} v\cos\theta \\ v\sin\theta \\ \frac{r(v_r - v_l)}{2R_w}\end{bmatrix} = \begin{bmatrix}\frac{(v_l + v_r)\cos\theta}{2} \\ \frac{(v_l + v_r)\sin\theta}{2} \\ \frac{r(v_r - v_l)}{2R_w}\end{bmatrix}$$

Inputs:

v_l = left wheel velocity

v_r = right wheel velocity


Navigation Module
Initial Pose
GOAL
Path Planning
X,y, tita
Controlador
Motor 1
Motor 2
Predictvo
SLAM
Estimado

TP4: Navegación, planificación y control en el propio diseño robot simulado, usando ROS?

https://www.youtube.com/watch?v=OWeLUSzxMsw&list=PLunhqkrRNRhYAffV8JDiFOatQXuU-NnxT