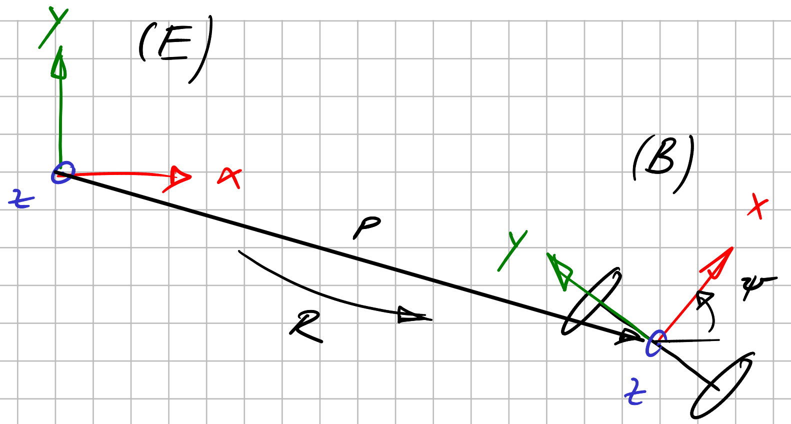
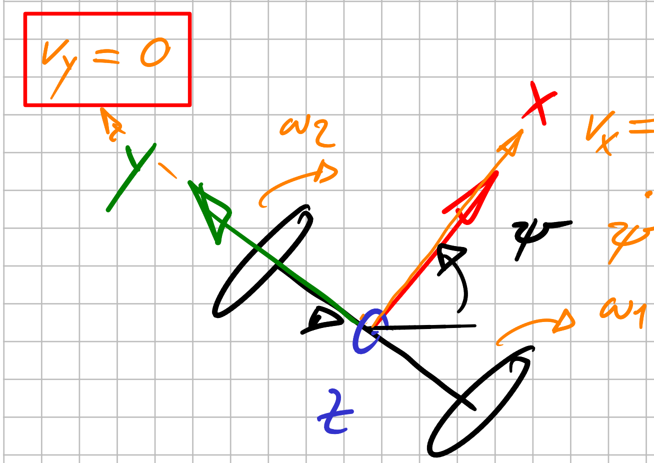


Position $p = \begin{pmatrix} x \\ y \end{pmatrix}$

Orientation ψ



$v_x = v$ forward velocity

$\dot\psi = \omega$ turn rate

$$\dot{\begin{pmatrix} x \\ y \\ \psi \end{pmatrix}} = \begin{pmatrix} \overbrace{\begin{pmatrix} \cos\psi & -\sin\psi \\ \sin\psi & \cos\psi \end{pmatrix}}^{R} & \begin{matrix} 0 \\ 0 \end{matrix} \\ \begin{matrix} 0 & 0 \end{matrix} & 1 \end{pmatrix} \begin{pmatrix} v \\ \boxed{0} \\ \omega \end{pmatrix}$$

$$\dot{\begin{pmatrix} x \\ y \\ \psi \end{pmatrix}} = \begin{pmatrix} \cos\psi & 0 \\ \sin\psi & 0 \\ 0 & 1 \end{pmatrix} \begin{pmatrix} v \\ \omega \end{pmatrix}$$

- This is how the robot integrates body velocities (v, ω) into it's pose (position & orientation)

- This $2 \mapsto 3$ map is a so called non holonomic constrain.

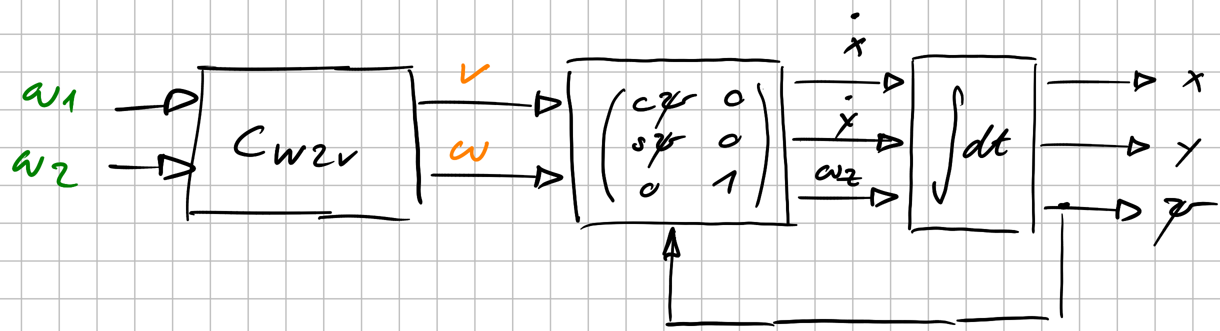
We can only control the motors

$$v = \frac{1}{2}\left(\omega_1 r_1 + \omega_2 r_2\right)$$

$$\omega = \frac{1}{b}\left(\omega_1 r_1 - \omega_2 r_2\right)$$

$$\begin{pmatrix} v \\ \omega \end{pmatrix} = \underbrace{\begin{pmatrix} r_1/2 & r_2/2 \\ r_1/b & -r_2/b \end{pmatrix}}_{C_{w2r}} \begin{pmatrix} \omega_1 \\ \omega_2 \end{pmatrix}$$

Block Diagram



Uncertainties

$$\omega_1 = \omega_{0,1} + \Delta\omega_1 \qquad \frac{\Delta\omega_1}{\omega_{0,1}} \ll 1$$

$$\omega_2 = \omega_{0,2} + \Delta\omega_2 \qquad \frac{\Delta\omega_2}{\omega_{0,2}} \ll 1$$

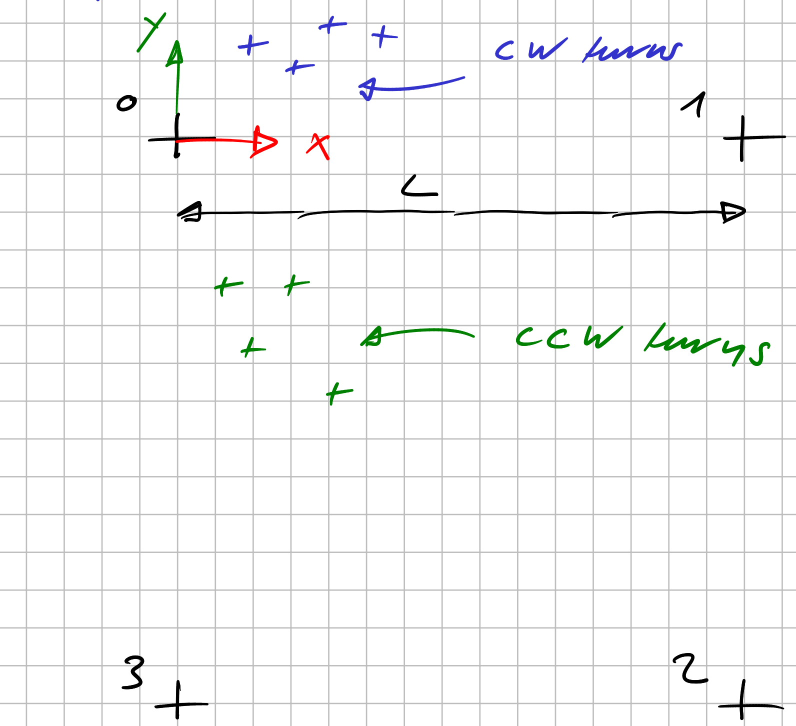
↳ neglectable, because we run the motors in closed-loop

$$r_1 = r_{0,1} + \Delta r_1$$
$$r_2 = r_{0,2} + \Delta r_2$$
$$b = b_0 + \Delta b$$

↳ uncertainties NOT neglectable, but can be calibrated

→ see paper

Experiment



- Square with length L
- 4 CW rounds
- 4 CCW rounds
- Measure errors
- calibrate?

Sequence:

- 0 → 1
- 90° turn
- 1 → 2
- 90° turn
- 2 → 3
- 90° turn
- 3 → 4
- 90° turn

Relative Positioning

pure forward motion

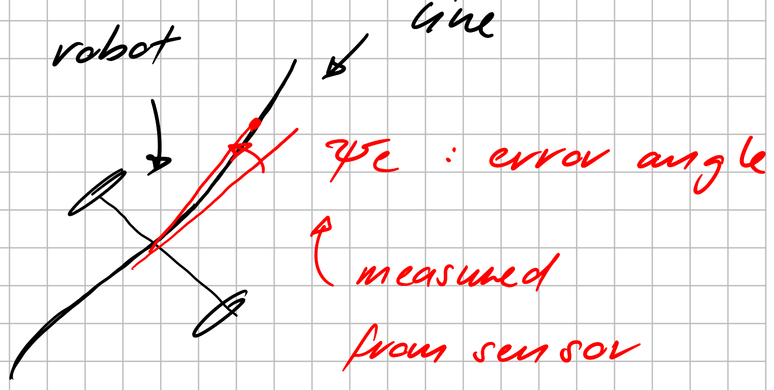
$$\begin{pmatrix} \Delta\varphi_1 \\ \Delta\varphi_2 \end{pmatrix} = C_{w2r}^{-1} \begin{pmatrix} \Delta L \\ 0 \end{pmatrix}$$

pure turn motion

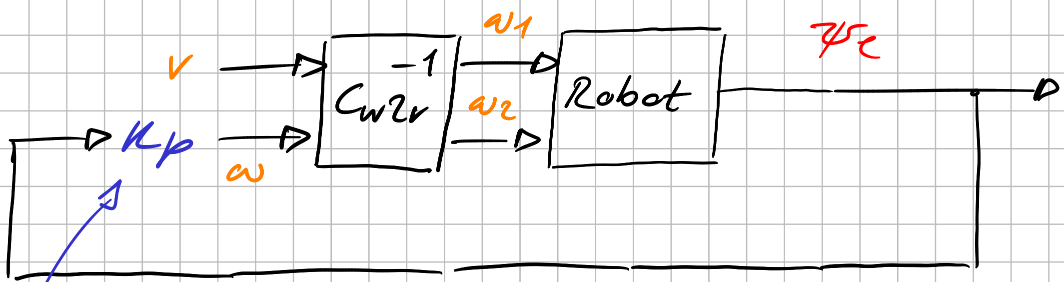
$$\begin{pmatrix} \Delta\varphi_1 \\ \Delta\varphi_2 \end{pmatrix} = C_{w2r}^{-1} \begin{pmatrix} 0 \\ \Delta\psi \end{pmatrix}$$

Following a Line

"simple" approach

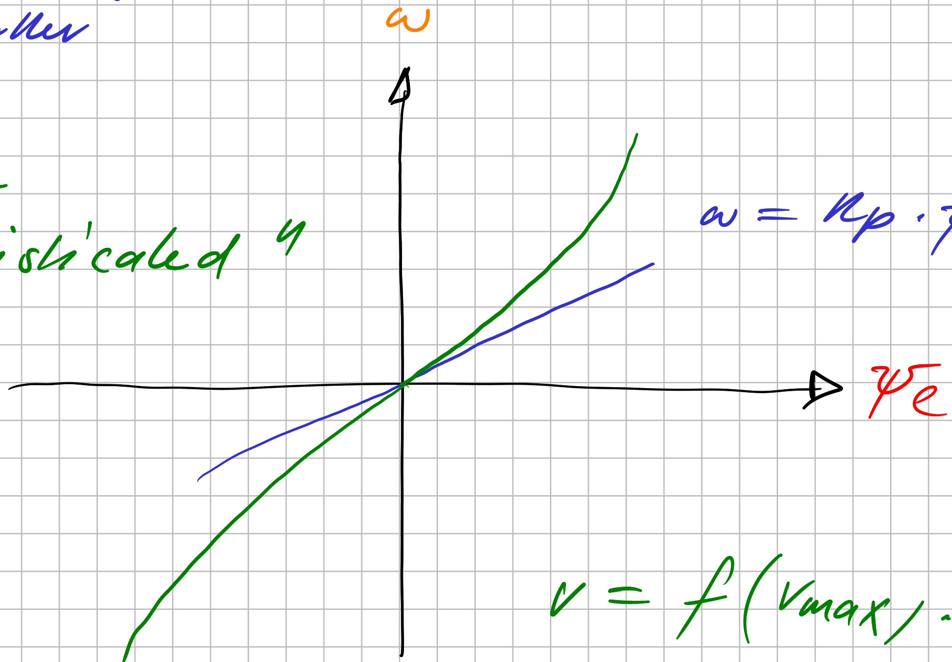


$v = \frac{1}{2} v_{max}$



simple P-type controller

"more sophisticated"



$v = f(v_{max}, \ldots)$

$$\omega = \underbrace{K_p \cdot \psi_e}_{\text{linear}} + \underbrace{K_{p,nl} \cdot |\psi_e| \psi_e}_{\text{quadratic}}$$