

CONTROLE \mathcal{H}_∞ NÃO LINEAR DE ROBÔS MÓVEIS COM RODAS

Gilson Antonio dos Reis

Orientador: Prof. Dr. Marco Henrique Terra

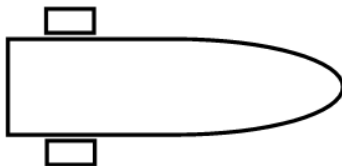
- 1- Introdução
- 2- Modelagem do Robô
- 3- Controlador baseado na cinemática
- 4- Controladores baseados na dinâmica
- 5- Resultados em simulação
- 6- Implementação do módulo de visão
- 7- Conclusão e trabalho futuro

- Motivação

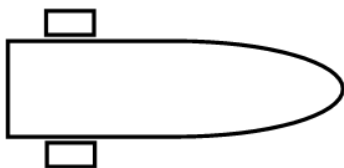
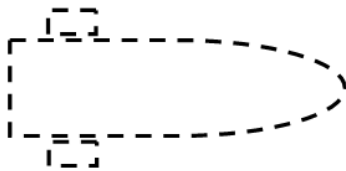
- Motivação
- Objetivo

- Motivação
- Objetivo
- Restrições Cinemáticas

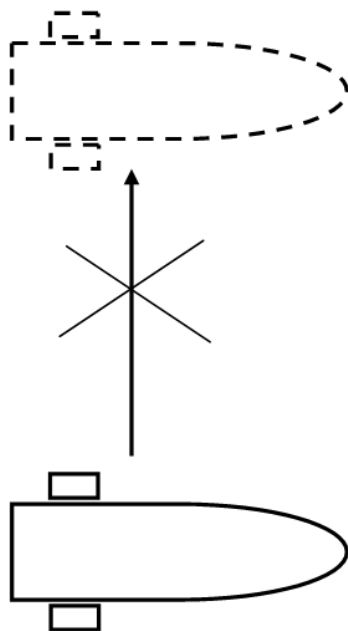
- Motivação
- Objetivo
- Restrições Cinemáticas



- Motivação
- Objetivo
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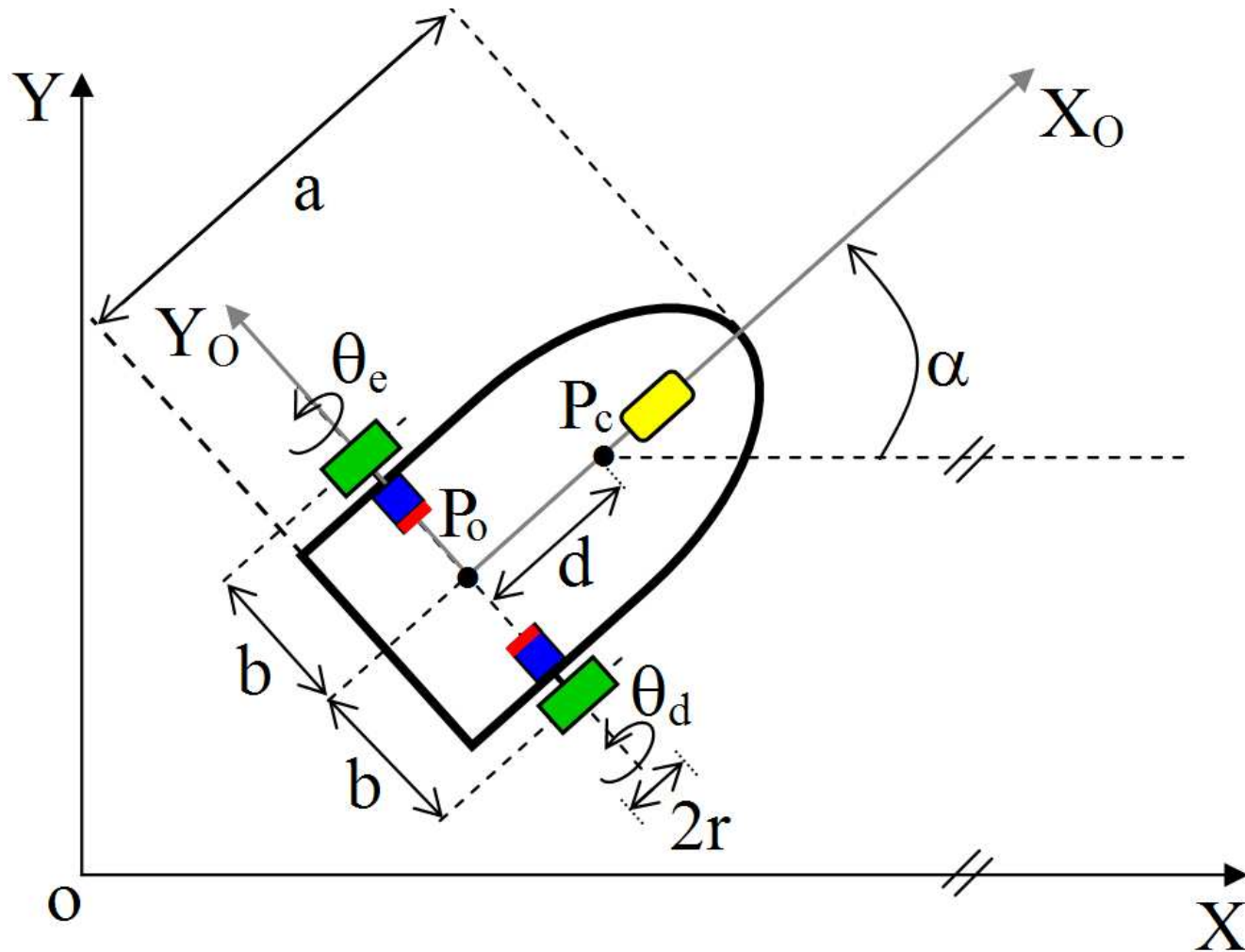
- Motivação
- Objetivo
- Restrições Cinemáticas



- Motivação
- Objetivo
- Restrições Cinemáticas
- Leis de controle

- Motivação
- Objetivo
- Restrições Cinemáticas
- Leis de controle
- Localização de RMRs

2- Modelagem do Robô



- **Modelo cinemático**

- **Modelo cinemático**

$$\dot{q}(t) = S_o(q)\dot{q}_2(t) \text{ sendo } q = [x_o \ y_o \ \alpha \ \theta_d \ \theta_e]^T \text{ e}$$
$$q_2 = [\theta_d \ \theta_e]^T$$

- **Modelo cinemático**

$$\dot{q}(t) = S_o(q)\dot{q}_2(t) \text{ sendo } q = [x_o \ y_o \ \alpha \ \theta_d \ \theta_e]^T \text{ e}$$
$$q_2 = [\theta_d \ \theta_e]^T$$

ou

$$\dot{x}_o = \frac{r}{2}\cos(\alpha)\dot{\theta}_d + \frac{r}{2}\cos(\alpha)\dot{\theta}_e$$

$$\dot{y}_o = \frac{r}{2}\sen(\alpha)\dot{\theta}_d + \frac{r}{2}\sen(\alpha)\dot{\theta}_e$$

$$\dot{\alpha} = \frac{r}{2b}(\dot{\theta}_d - \dot{\theta}_e)$$

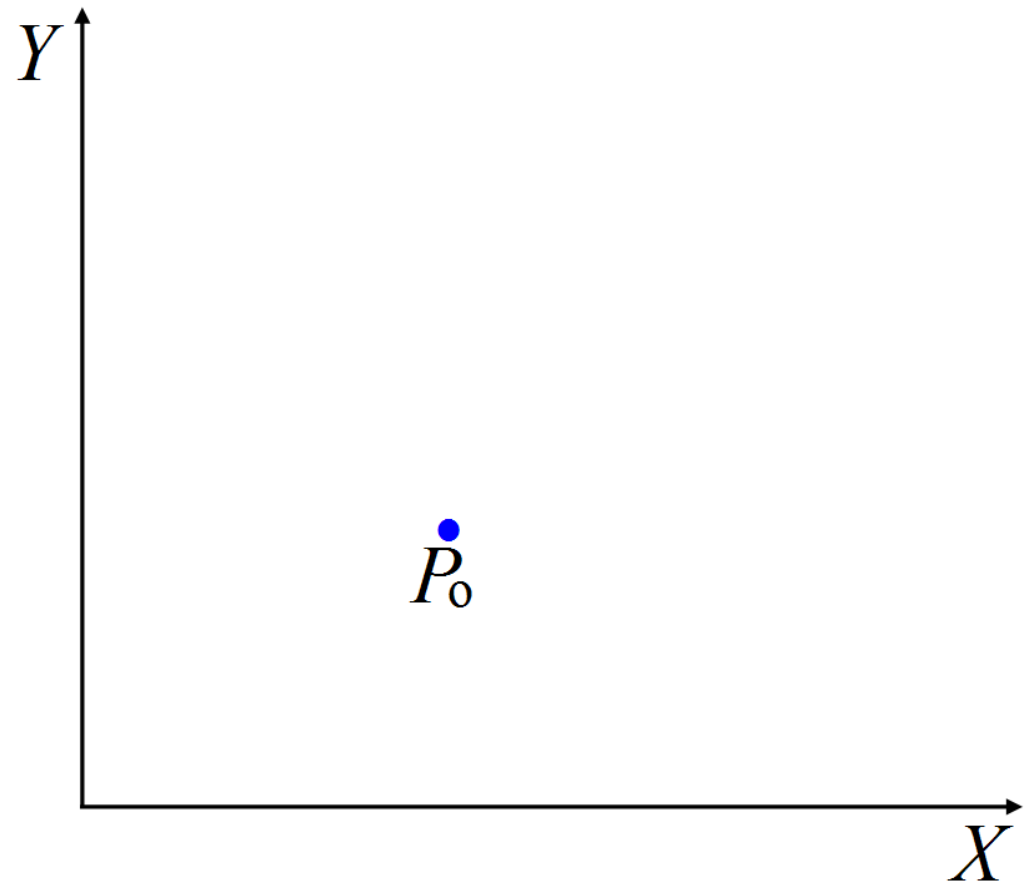
- **Modelo dinâmico**

$$M(q_1)\ddot{q}_1 + C(q_1, \dot{q}_1)\dot{q}_1 = E\tau - A_c(q_1)^T \lambda$$

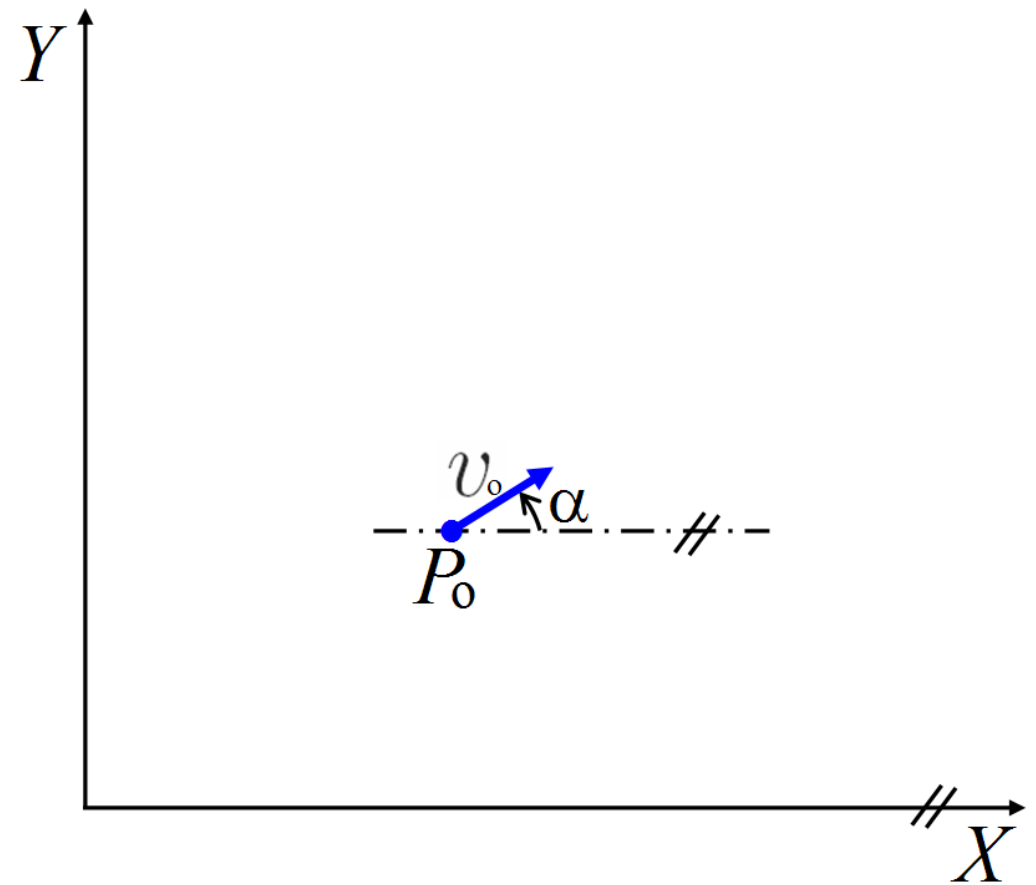
sendo $q_1 = [x_c \ y_c \ \alpha \ \theta_d \ \theta_e]^T$

$$M = \begin{bmatrix} m & 0 & 2m_r d \sin(\alpha) & 0 & 0 \\ 0 & m & -2m_r d \cos(\alpha) & 0 & 0 \\ 2m_r d \sin(\alpha) & -2m_r d \cos(\alpha) & I & 0 & 0 \\ 0 & 0 & 0 & I_r & 0 \\ 0 & 0 & 0 & 0 & I_r \end{bmatrix}, C = \begin{bmatrix} 0 & 0 & 2m_r d \dot{\alpha} \cos(\alpha) & 0 & 0 \\ 0 & 0 & 2m_r d \dot{\alpha} \sin(\alpha) & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

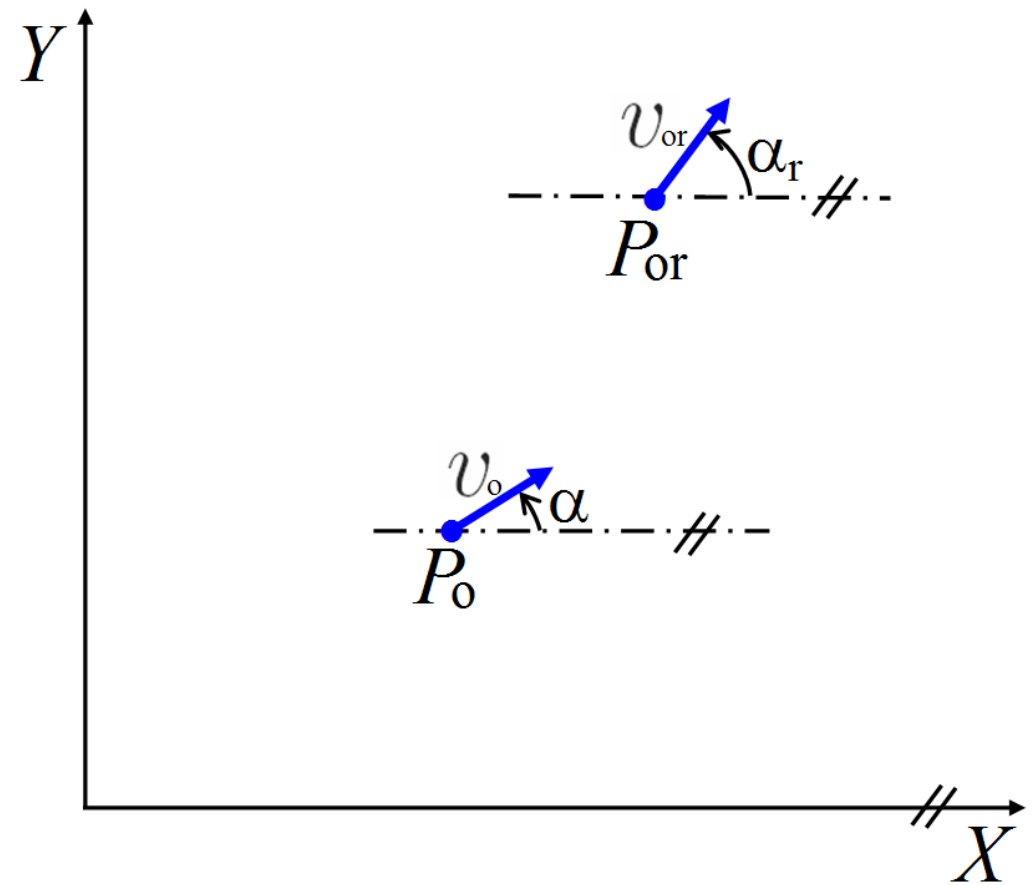
3- Controle baseado na cinemática



3- Controle baseado na cinemática

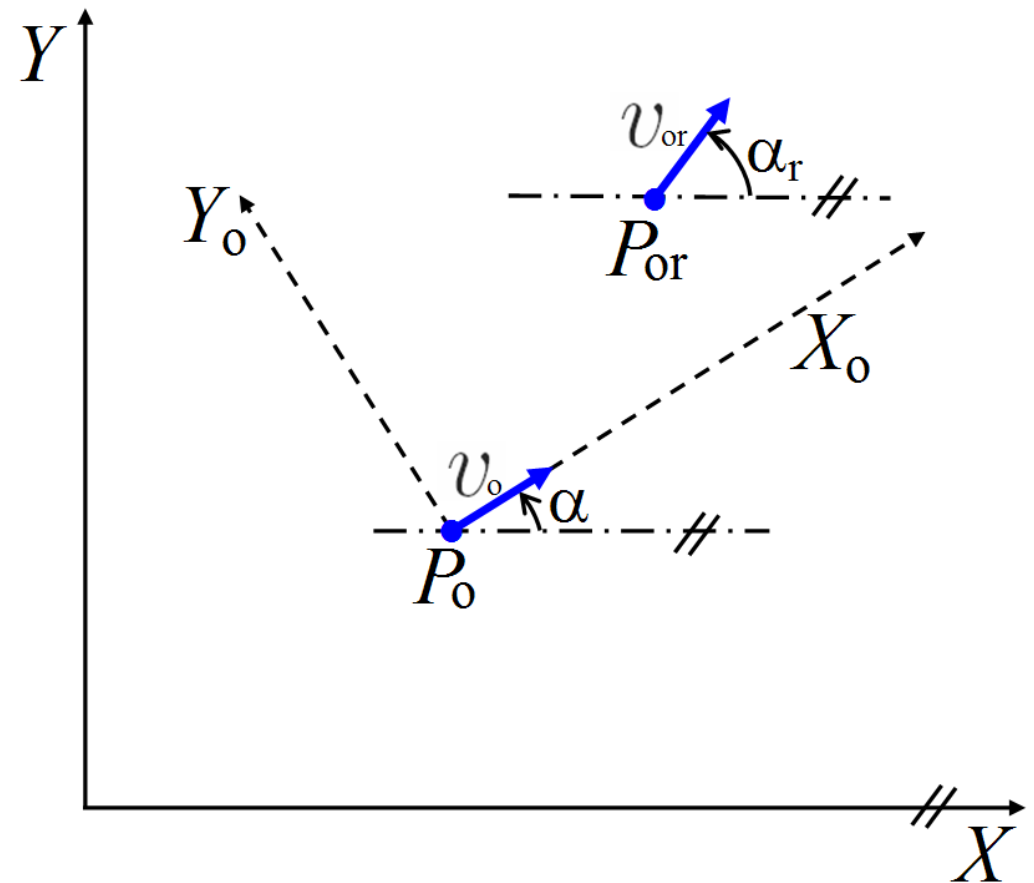


3- Controle baseado na cinemática



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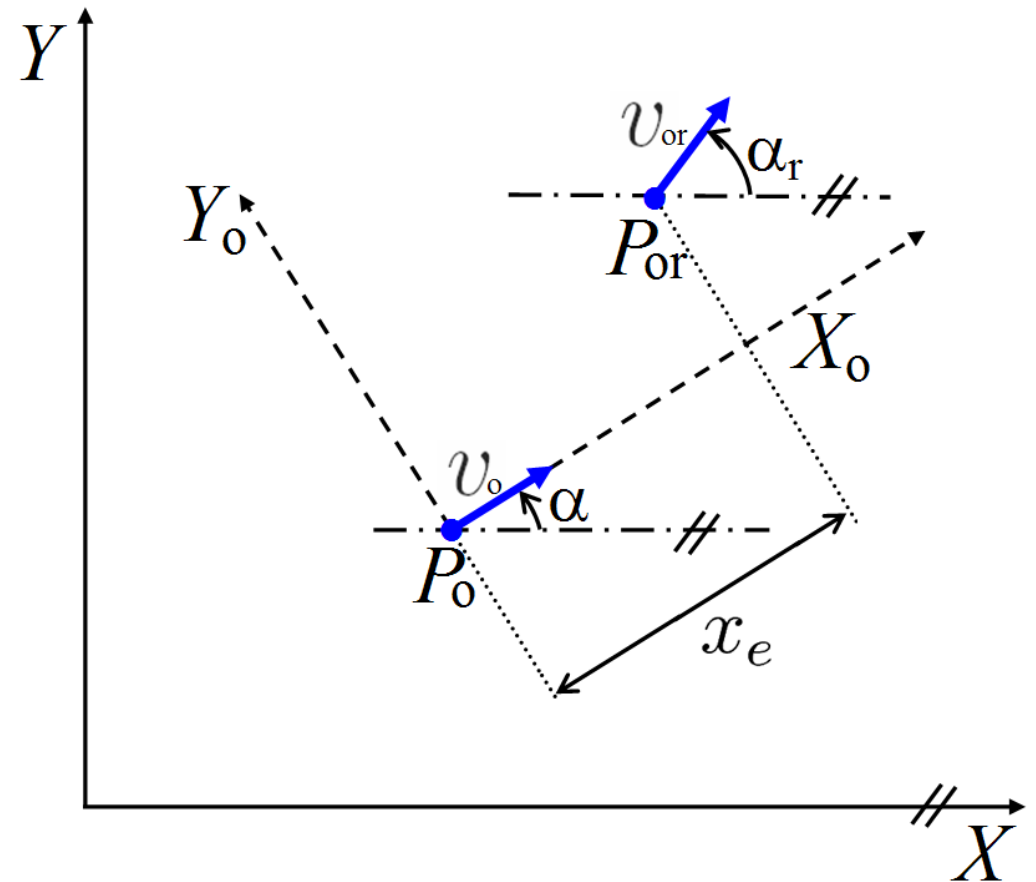
- Erro de postura



3- Controle baseado na cinemática

- **Erro de postura**

$$x_e = (x_r - x_o)\cos(\alpha) + (y_r - y_o)\sin(\alpha)$$

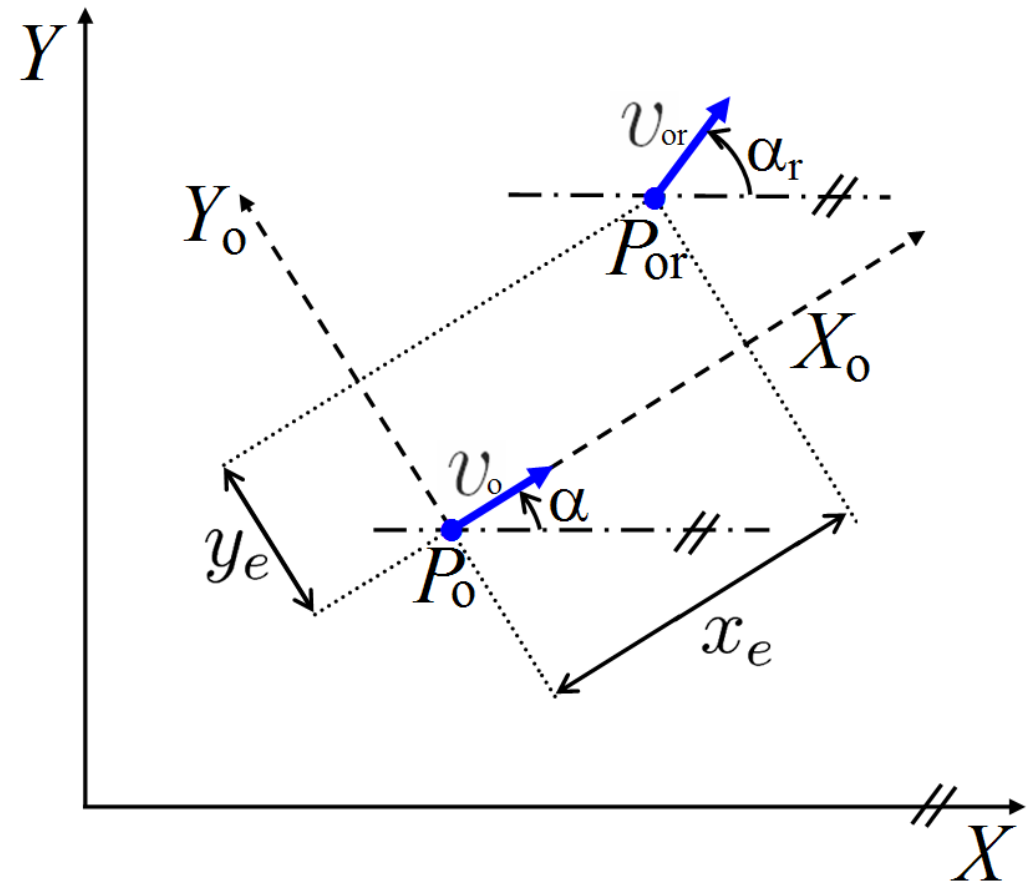


3- Controle baseado na cinemática

- **Erro de postura**

$$x_e = (x_r - x_o)\cos(\alpha) + (y_r - y_o)\sen(\alpha)$$

$$y_e = -(x_r - x_o)\sen(\alpha) + (y_r - y_o)\cos(\alpha)$$



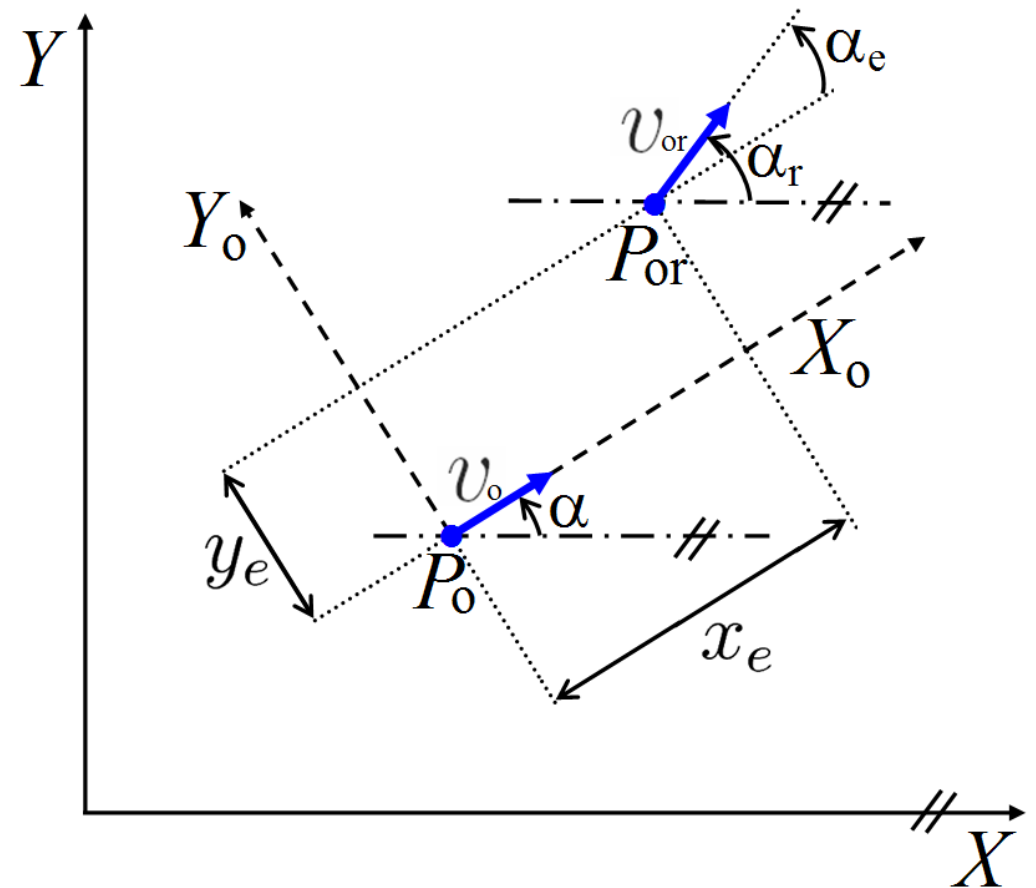
3- Controle baseado na cinemática

- **Erro de postura**

$$x_e = (x_r - x_o)\cos(\alpha) + (y_r - y_o)\sin(\alpha)$$

$$y_e = -(x_r - x_o)\sin(\alpha) + (y_r - y_o)\cos(\alpha)$$

$$\alpha_e = \alpha_r - \alpha$$



3- Controle baseado na cinemática

- **Lei de controle**[KANAYAMA et al. (1990)]

3- Controle baseado na cinemática

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$$v^{\mathbf{d}} = v_{or} \cos(\alpha_e) + k_x x_e$$

$$\omega^{\mathbf{d}} = \omega_r + v_{or} (k_y y_e + k_\alpha \sin(\alpha_e))$$

3- Controle baseado na cinemática

- **Lei de controle**[KANAYAMA et al. (1990)]

$$v^{\mathbf{d}} = v_{or} \cos(\alpha_e) + k_x x_e$$

$$\omega^{\mathbf{d}} = \omega_r + v_{or} (k_y y_e + k_\alpha \sin(\alpha_e))$$

- Relação entre velocidades

$$\dot{q}_2^{\mathbf{d}} = \begin{bmatrix} \dot{\theta}_d^{\mathbf{d}} \\ \dot{\theta}_e^{\mathbf{d}} \end{bmatrix} = \begin{bmatrix} 1/r & b/r \\ 1/r & -b/r \end{bmatrix} \begin{bmatrix} v^{\mathbf{d}} \\ \omega^{\mathbf{d}} \end{bmatrix}$$

Controle \mathcal{H}_∞ não Linear via quase-LPV

- Análise do ganho \mathcal{L}_2

Controle \mathcal{H}_∞ não Linear via quase-LPV

- **Análise do ganho \mathcal{L}_2**

Considere

$$\begin{cases} \dot{x} = f(x, t) + g(x, t)w \\ z = h(x, t) + k(x, t)w \end{cases}$$

Controle \mathcal{H}_∞ não Linear via quase-LPV

- **Análise do ganho \mathcal{L}_2**

Considere

$$\begin{cases} \dot{x} = f(x, t) + g(x, t)w \\ z = h(x, t) + k(x, t)w \end{cases}$$

Este sistema possui ganho $\mathcal{L}_2 \leq \gamma$ no intervalo $[0, T]$

se

$$\int_0^T \|z(t)\|^2 dt \leq \gamma^2 \int_0^T \|w(t)\|^2 dt$$

Controle \mathcal{H}_∞ não Linear via quase-LPV

- Síntese do controle \mathcal{H}_∞ para sistema LPV por realimentação de estado

Controle \mathcal{H}_∞ não Linear via quase-LPV

- Síntese do controle \mathcal{H}_∞ para sistema LPV por realimentação de estado

Considere

$$\begin{cases} \dot{x} = A(\rho(t))x + B_1(\rho(t))w + B_2(\rho(t))u \\ z_1 = C_1(\rho(t))x \\ z_2 = C_2(\rho(t))x + u \end{cases}$$

Controle \mathcal{H}_∞ não Linear via quase-LPV

- Síntese do controle \mathcal{H}_∞ para sistema LPV por realimentação de estado

Considere

$$\begin{cases} \dot{x} = A(\rho(t))x + B_1(\rho(t))w + B_2(\rho(t))u \\ z_1 = C_1(\rho(t))x \\ z_2 = C_2(\rho(t))x + u \end{cases}$$

$$F_P^\nu = \{ \rho \in \mathcal{C}^1 : \rho(t) \in P, |\dot{\rho}_i| \leq \nu_i, i = 1, \dots, m \}$$

Controle \mathcal{H}_∞ não Linear via quase-LPV

Teorema 1[WU (1995)] O problema de realimentação de estado tem solução se e somente se existe $X \in C^1$ para todo $\rho \in P$, $X(\rho) > 0$ e

$$\begin{bmatrix} G(\rho) & X(\rho)C_1^T(\rho) & B_1(\rho) \\ C_1(\rho)X(\rho) & -I & 0 \\ B_1^T(\rho) & 0 & -\gamma^2 I \end{bmatrix} < 0$$

Controle \mathcal{H}_∞ não Linear via quase-LPV

sendo

$$G(\rho) = -\sum_{i=1}^m \pm \left(\nu_i \frac{\partial X}{\partial \rho_i} \right) + \hat{A}(\rho) X(\rho) + X(\rho) \hat{A}(\rho)^T - B_2(\rho) B_2^T(\rho),$$

$$\hat{A}(\rho) = A(\rho) - B_2(\rho) C_2(\rho)$$

Controle \mathcal{H}_∞ não Linear via quase-LPV

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com

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com

$$u = -F(\rho)x = -(B_2(\rho)^T X^{-1}(\rho) + C_2(\rho))x$$

Controle \mathcal{H}_∞ não Linear via quase-LPV

sendo

$$G(\rho) = -\sum_{i=1}^m \pm \left(\nu_i \frac{\partial X}{\partial \rho_i} \right) + \hat{A}(\rho) X(\rho) + X(\rho) \hat{A}(\rho)^T - B_2(\rho) B_2^T(\rho),$$

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- Considerações computacionais

Controle \mathcal{H}_∞ não Linear via quase-LPV

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$$\hat{A}(\rho) = A(\rho) - B_2(\rho) C_2(\rho)$$

com

$$u = -F(\rho)x = -(B_2(\rho)^T X^{-1}(\rho) + C_2(\rho))x$$

- Considerações computacionais

Escolha de $\{f_i(\rho)\}_{i=1}^M$, tal que $X(\rho) = \sum_{i=1}^M f_i(\rho) X_i$

Controle \mathcal{H}_∞ não Linear via quase-LPV

- Representação quase LPV do modelo dinâmico

Controle \mathcal{H}_∞ não Linear via quase-LPV

- Representação quase LPV do modelo dinâmico

$$\dot{\tilde{x}} = \begin{bmatrix} A(\dot{q}_2) & 0 \\ I & 0 \end{bmatrix} \tilde{x} + \begin{bmatrix} I \\ 0 \end{bmatrix} u + \begin{bmatrix} B \\ 0 \end{bmatrix} w$$

Controle \mathcal{H}_∞ não Linear via quase-LPV

- Representação quase LPV do modelo dinâmico

$$\dot{\tilde{x}} = \begin{bmatrix} A(\dot{q}_2) & 0 \\ I & 0 \end{bmatrix} \tilde{x} + \begin{bmatrix} I \\ 0 \end{bmatrix} u + \begin{bmatrix} B \\ 0 \end{bmatrix} w$$

sendo

$$\tilde{x} = \begin{bmatrix} \dot{\tilde{q}}_2 & \tilde{q}_2 \end{bmatrix}^T = \begin{bmatrix} \dot{\theta}_d - \dot{\theta}_d^d & \dot{\theta}_e - \dot{\theta}_e^d & \theta_d - \theta_d^d & \theta_e - \theta_e^d \end{bmatrix}^T,$$

$$u = -\ddot{q}_2^d + A\dot{q}_2^d + B\tau \quad \text{ou} \quad \tau = B^{-1}(\ddot{q}_2^d - A\dot{q}_2^d + u)$$

Controle \mathcal{H}_∞ não Linear via Teoria dos Jogos

Aplicando

$$\tilde{z} = \begin{bmatrix} \tilde{z}_1 \\ \tilde{z}_2 \end{bmatrix} = T_0 \tilde{x} = \begin{bmatrix} t_{11}I & T_{12} \\ 0 & I \end{bmatrix} \begin{bmatrix} \dot{\tilde{q}}_2 \\ \tilde{q}_2 \end{bmatrix}$$

em

$$\dot{\tilde{x}} = \begin{bmatrix} A(\dot{q}_2) & 0 \\ I & 0 \end{bmatrix} \tilde{x} + \begin{bmatrix} I \\ 0 \end{bmatrix} u + \begin{bmatrix} B \\ 0 \end{bmatrix} w,$$

obtém-se

4- Controle baseado na dinâmica

Controle \mathcal{H}_∞ não Linear via Teoria dos Jogos

$$\dot{\tilde{x}} = A_T \tilde{x} + B_{T_1} u + B_{T_2} w$$

4- Controle baseado na dinâmica

Controle \mathcal{H}_∞ não Linear via Teoria dos Jogos

$$\dot{\tilde{x}} = A_T \tilde{x} + B_{T_1} u + B_{T_2} w$$

sendo $A_T = T_0^{-1} \begin{bmatrix} A(\dot{q}_2) & 0 \\ T_{11}^{-1} & -T_{11}^{-1} T_{12} \end{bmatrix} T_0,$

$$B_{T_1} = T_0^{-1} \begin{bmatrix} M_2^{-1} \\ 0 \end{bmatrix}, \quad B_{T_2} = B_{T_1} T_{11},$$

$$u = T_{11}(-M_2(\ddot{q}_2^d - T_{11}^{-1} T_{12} \dot{\tilde{q}}_2) - C_2(\dot{q}_2)(\dot{q}_2^d - T_{11}^{-1} T_{12} \tilde{q}_2) + \tau)$$

ou

$$\tau = M_2(\ddot{q}_2^d - T_{11}^{-1} T_{12} \dot{\tilde{q}}_2) + C_2(\dot{q}_2)(\dot{q}_2^d - T_{11}^{-1} T_{12} \tilde{q}_2) + T_{11}^{-1} u$$

Controle \mathcal{H}_∞ não Linear via Teoria dos Jogos

Critério de desempenho

$$\min_{u(\cdot) \in \mathcal{L}_2} \max_{0 \neq w(\cdot) \in \mathcal{L}_2} \frac{\int_0^\infty \left(\frac{1}{2} \tilde{x}^T(t) Q \tilde{x}(t) + \frac{1}{2} u^T(t) R u(t) \right) dt}{\int_0^\infty \left(\frac{1}{2} w^T(t) w(t) \right) dt} \leq \gamma^2$$

Controle \mathcal{H}_∞ não Linear via Teoria dos Jogos

Critério de desempenho

$$\min_{u(\cdot) \in \mathcal{L}_2} \max_{0 \neq w(\cdot) \in \mathcal{L}_2} \frac{\int_0^\infty \left(\frac{1}{2} \tilde{x}^T(t) Q \tilde{x}(t) + \frac{1}{2} u^T(t) R u(t) \right) dt}{\int_0^\infty \left(\frac{1}{2} w^T(t) w(t) \right) dt} \leq \gamma^2$$

Resolve o problema, escolhendo

$$V(\tilde{x}, t) = \frac{1}{2} \tilde{x}^T P(\tilde{x}, t) \tilde{x}$$

sendo $P(\tilde{x}, t) > 0$ que satisfaça

Controle \mathcal{H}_∞ não Linear via Teoria dos Jogos

$$\begin{aligned} & \dot{P}(\tilde{x}, t) + P(\tilde{x}, t)A_T(\tilde{x}, t) + A_T^T(\tilde{x}, t)P(\tilde{x}, t) \\ & - P(\tilde{x}, t)B_{T_1}(\tilde{x}, t)\left(R^{-1} - \frac{1}{\gamma^2}T_{11}^2\right)B_{T_1}^T(\tilde{x}, t)P(\tilde{x}, t) \\ & + Q = 0 \end{aligned}$$

Controle \mathcal{H}_∞ não Linear via Teoria dos Jogos

$$\begin{aligned} & \dot{P}(\tilde{x}, t) + P(\tilde{x}, t)A_T(\tilde{x}, t) + A_T^T(\tilde{x}, t)P(\tilde{x}, t) \\ & - P(\tilde{x}, t)B_{T_1}(\tilde{x}, t)\left(R^{-1} - \frac{1}{\gamma^2}T_{11}^2\right)B_{T_1}^T(\tilde{x}, t)P(\tilde{x}, t) \\ & + Q = 0 \end{aligned}$$

Com

$$u^* = -R^{-1}B_{T_1}^T(\tilde{x}, t)P(\tilde{x}, t)\tilde{x}$$

Controle \mathcal{H}_∞ não Linear via Teoria dos Jogos

Escolhendo

$$P(\tilde{x}, t) = T_0^T \begin{bmatrix} M_2 & 0 \\ 0 & K \end{bmatrix} T_0 \text{ e } \tilde{x}^T (C_2(\dot{q}_1) - \frac{1}{2} \dot{M}_2) \tilde{x} = 0$$

Controle \mathcal{H}_∞ não Linear via Teoria dos Jogos

Escolhendo

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O problema resume-se em calcular

$$\begin{bmatrix} 0 & K \\ K & 0 \end{bmatrix} - T_0^T [I \ 0]^T \left(R^{-1} - \frac{1}{\gamma^2} T_{11}^2 \right) [I \ 0] T_0 + Q = 0$$

Controle \mathcal{H}_∞ não Linear via Teoria dos Jogos

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Com $u^* = -R^{-1} [I \ 0] T_0 \tilde{x}$

Controle \mathcal{H}_∞ não Linear via Teoria dos Jogos

Considerando $Q = \begin{bmatrix} q_{11}I & q_{12}I \\ q_{12}I & q_{22}I \end{bmatrix},$

$K = kI, R = r_uI$ e $T_{12} = t_{12}I$

Controle \mathcal{H}_∞ não Linear via Teoria dos Jogos

$$\text{Considerando } Q = \begin{bmatrix} q_{11}I & q_{12}I \\ q_{12}I & q_{22}I \end{bmatrix},$$

$$K = kI, R = r_u I \text{ e } T_{12} = t_{12}I$$

Então

$$\gamma = \sqrt{\frac{t_{11}^4}{t_{11}^2 r_u^{-1} - q_{11}}},$$

$$t_{12} = \sqrt{\frac{q_{22}}{r_u^{-1} - \gamma^{-2} t_{11}^2}}$$

$$k = t_{11} t_{12} r_u^{-1} - q_{12} - \gamma^{-2} t_{11}^3 t_{12}$$

Controle \mathcal{H}_∞ não Linear via Teoria dos Jogos

$$\text{Considerando } Q = \begin{bmatrix} q_{11}I & q_{12}I \\ q_{12}I & q_{22}I \end{bmatrix},$$

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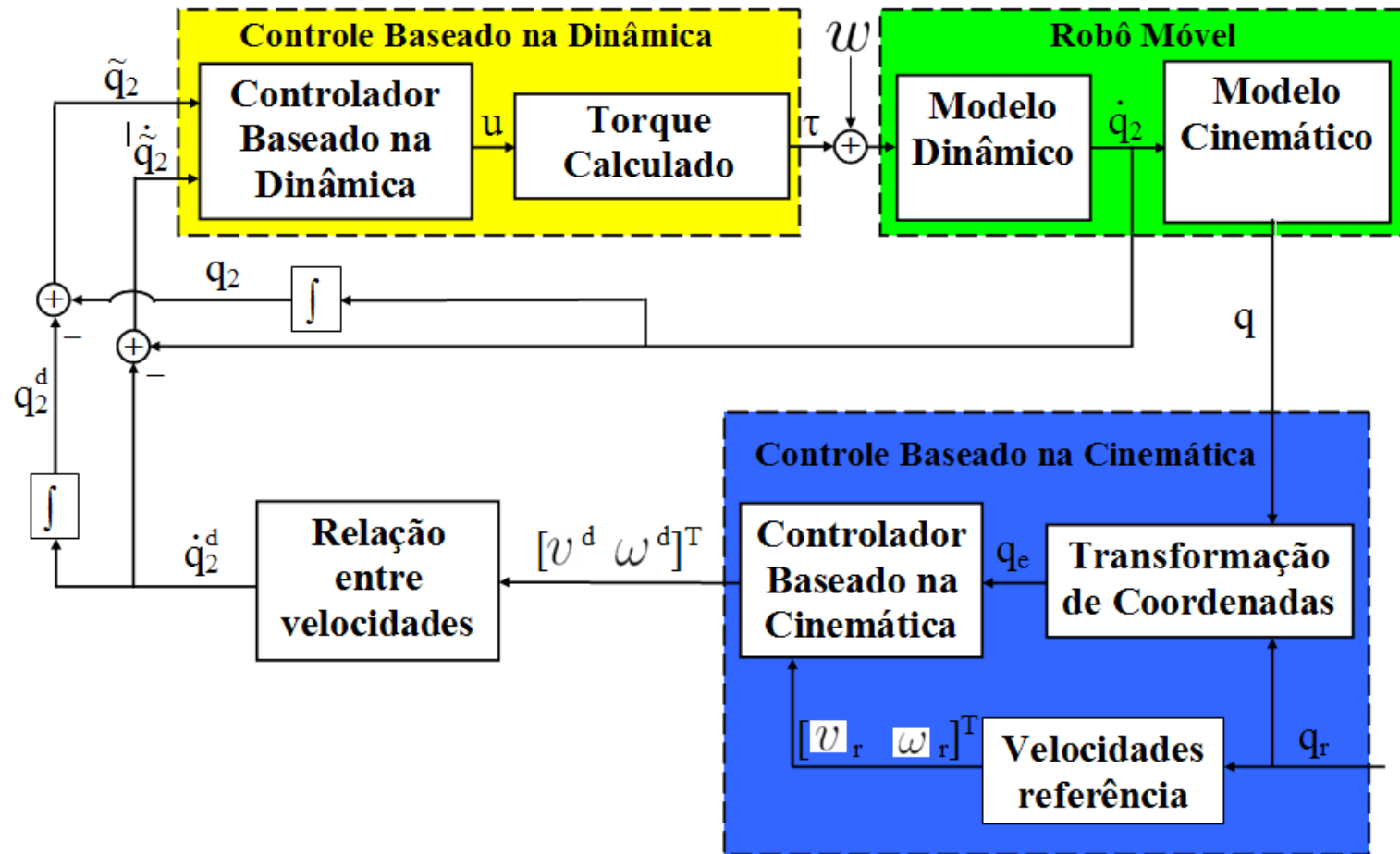
Então

$$\gamma = \sqrt{\frac{t_{11}^4}{t_{11}^2 r_u^{-1} - q_{11}}} \quad \Rightarrow \quad t_{11} > \sqrt{q_{11} r_u}$$

$$t_{12} = \sqrt{\frac{q_{22}}{r_u^{-1} - \gamma^{-2} t_{11}^2}}$$

$$k = t_{11} t_{12} r_u^{-1} - q_{12} - \gamma^{-2} t_{11}^3 t_{12}$$

Simulação dos controladores



Simulação dos controladores

- Plataforma LABMATE

$$m_p = 30(Kg), m_r = 1(Kg)$$

$$a = 2(m), b = 0.75(m), d = 0.3(m), r = 0.15(m)$$

$$I_c = 15.625(Kg.m^2), I_r = 0.005(Kg.m^2),$$

$$I_m = 0.0025(Kg.m^2)$$

Simulação dos controladores

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- Incerteza 10%

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- Incerteza 10%
- Ganhos controlador cinemático

$$k_x = 7, \quad k_y = 52 \text{ e } k_\alpha = 27$$

Simulação dos controladores

- Plataforma LABMATE

$$m_p = 30(Kg), m_r = 1(Kg)$$

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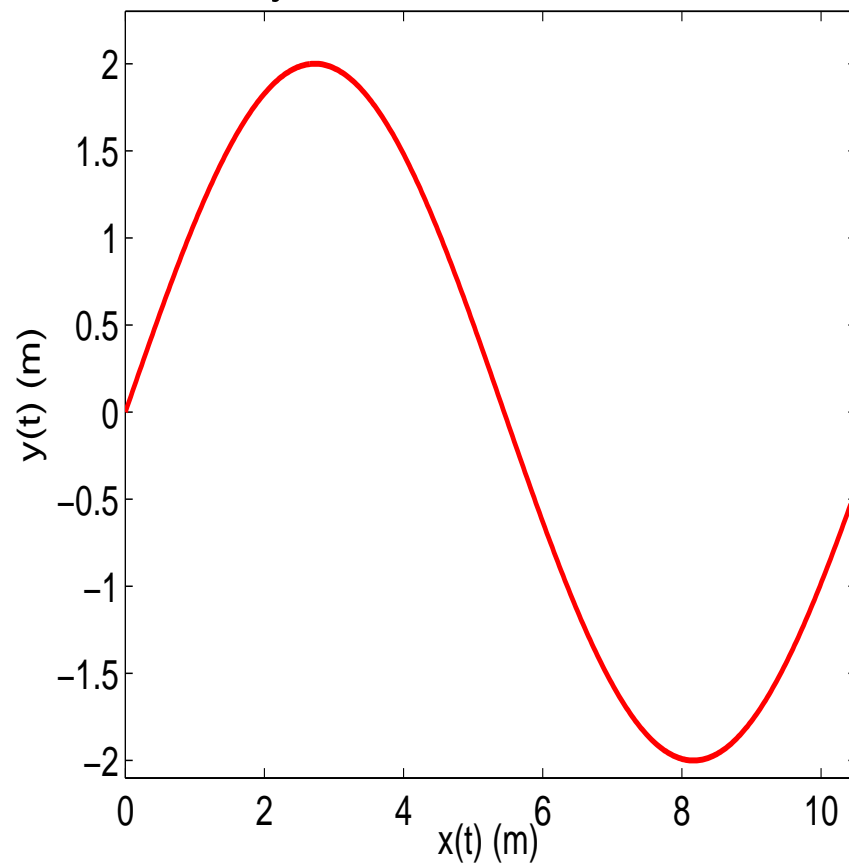
- Ganhos controlador cinemático

$$k_x = 7, \quad k_y = 52 \text{ e } k_\alpha = 27$$

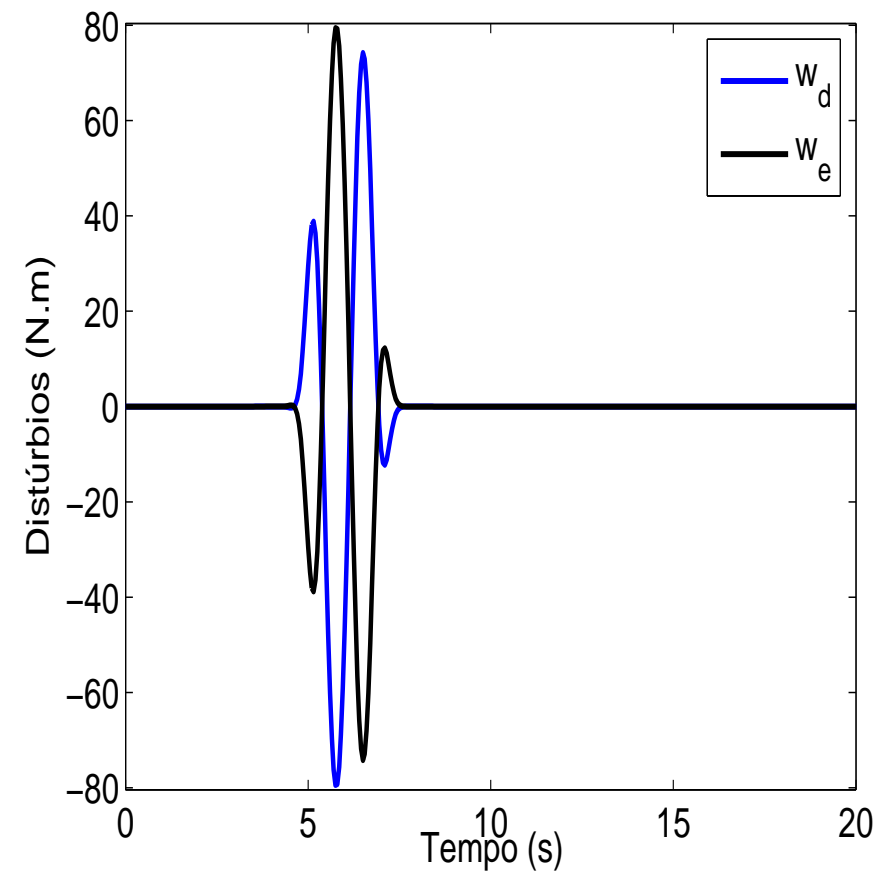
- Postura inicial $(x_{o_o}, y_{o_o}, \alpha_o) = (0, 0, 0)$

Simulação dos controladores

Trajétoria de referência



Distúrbios



Controle via quase-LPV

Controle via quase-LPV

$$-\pi \leq \dot{\tilde{\theta}}_d \leq \pi(\text{rad/s}) \quad \text{e} \quad -\pi \leq \dot{\tilde{\theta}}_e \leq \pi(\text{rad/s})$$

Controle via quase-LPV

$$-\pi \leq \dot{\tilde{\theta}}_d \leq \pi(\text{rad/s}) \quad \text{e} \quad -\pi \leq \dot{\tilde{\theta}}_e \leq \pi(\text{rad/s})$$

$$\nu = [\ddot{\tilde{\theta}}_{d_{max}} \quad \ddot{\tilde{\theta}}_{e_{max}}] = [2.5\pi \quad 2.5\pi](\text{rad/s}^2)$$

Controle via quase-LPV

$$-\pi \leq \dot{\tilde{\theta}}_d \leq \pi(\text{rad/s}) \quad \text{e} \quad -\pi \leq \dot{\tilde{\theta}}_e \leq \pi(\text{rad/s})$$

$$\nu = [\ddot{\tilde{\theta}}_{d_{max}} \quad \ddot{\tilde{\theta}}_{e_{max}}] = [2.5\pi \quad 2.5\pi](\text{rad/s}^2)$$

P dividido em $N = 3$

Controle via quase-LPV

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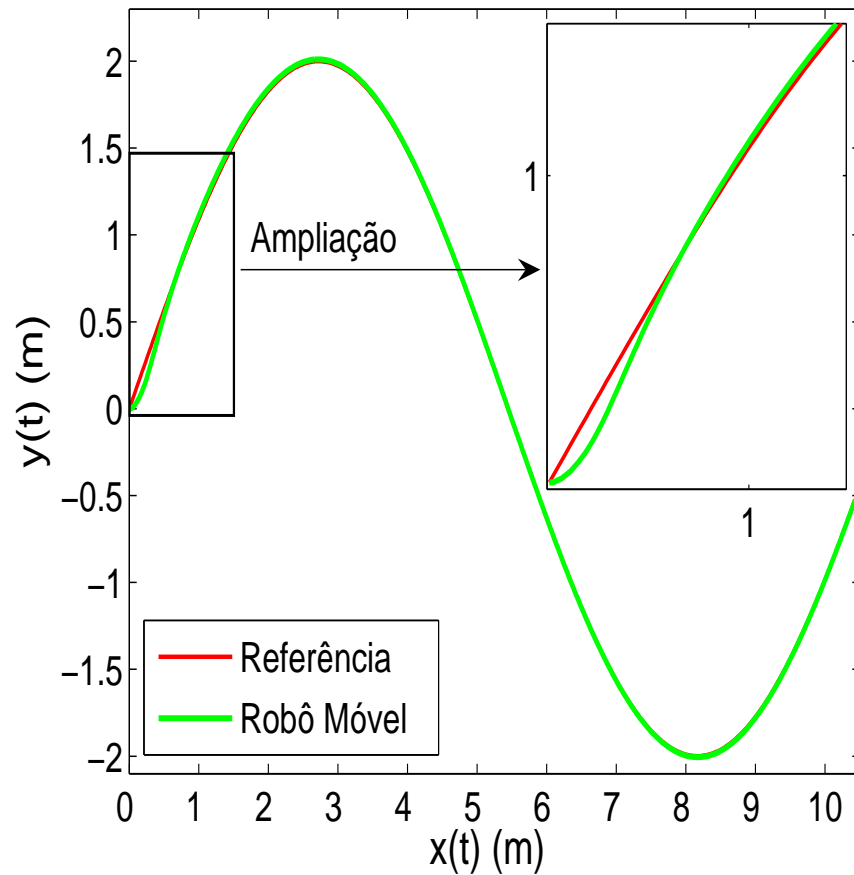
P dividido em $N = 3$

$$f_1 = 1, \quad f_2 = \cos\dot{\tilde{\theta}}_d \text{ e } f_3 = \sin\dot{\tilde{\theta}}_e$$

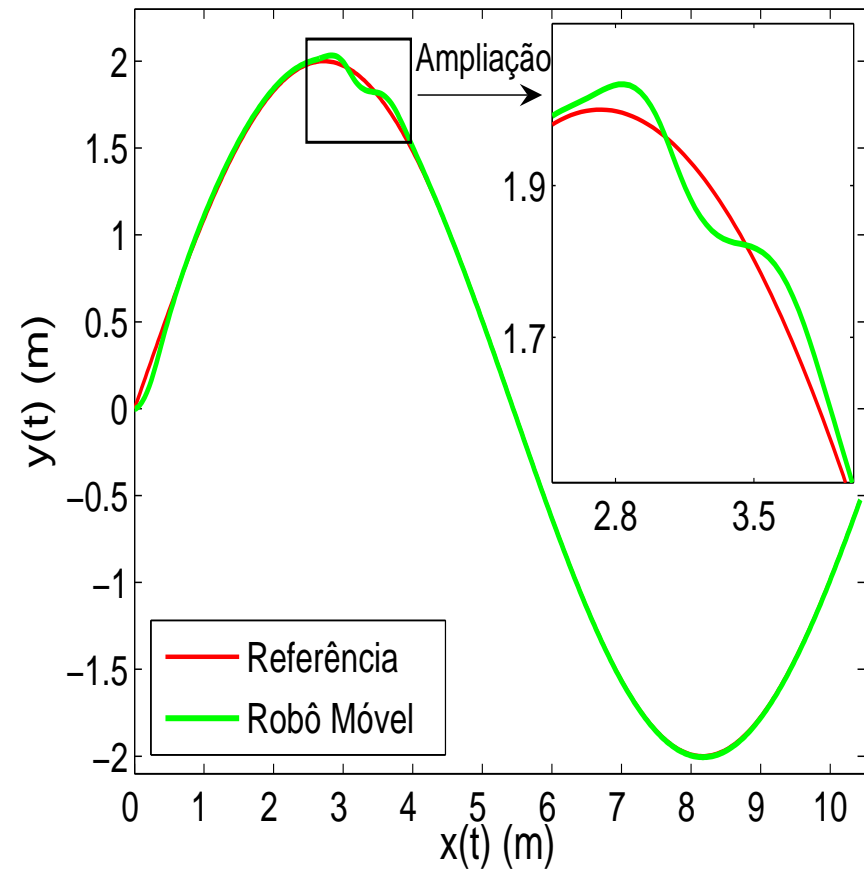
$$x = \tilde{x}, \quad C_1 = I_{4 \times 4} \text{ e } C_2 = 0$$

$$A(\rho(t)) = \begin{bmatrix} A(\dot{q}_2) & 0 \\ I & 0 \end{bmatrix}, \quad B_2 = \begin{bmatrix} I_{2 \times 2} \\ 0 \end{bmatrix}, \quad B_1 = \begin{bmatrix} B \\ 0 \end{bmatrix}$$

Controle via quase-LPV



Sem distúrbios



Com distúrbios

Controle via Teoria dos Jogos

Controle via Teoria dos Jogos

Valores escolhidos: $q_{11} = 0.3$

$$q_{12} = 0$$

$$q_{22} = 1.2$$

$$r_u = 0.7$$

Controle via Teoria dos Jogos

Valores escolhidos: $q_{11} = 0.3$

$$q_{12} = 0$$

$$q_{22} = 1.2$$

$$r_u = 0.7$$

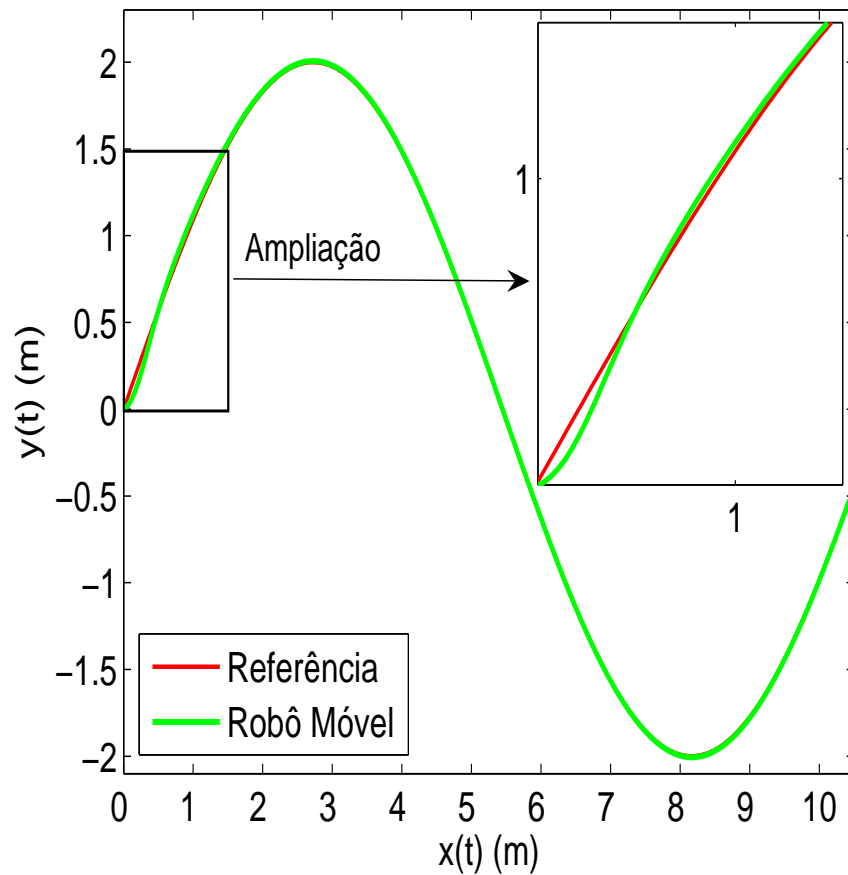
Obteve-se: $t_{11} = 0.65$

$$\gamma = 0.77$$

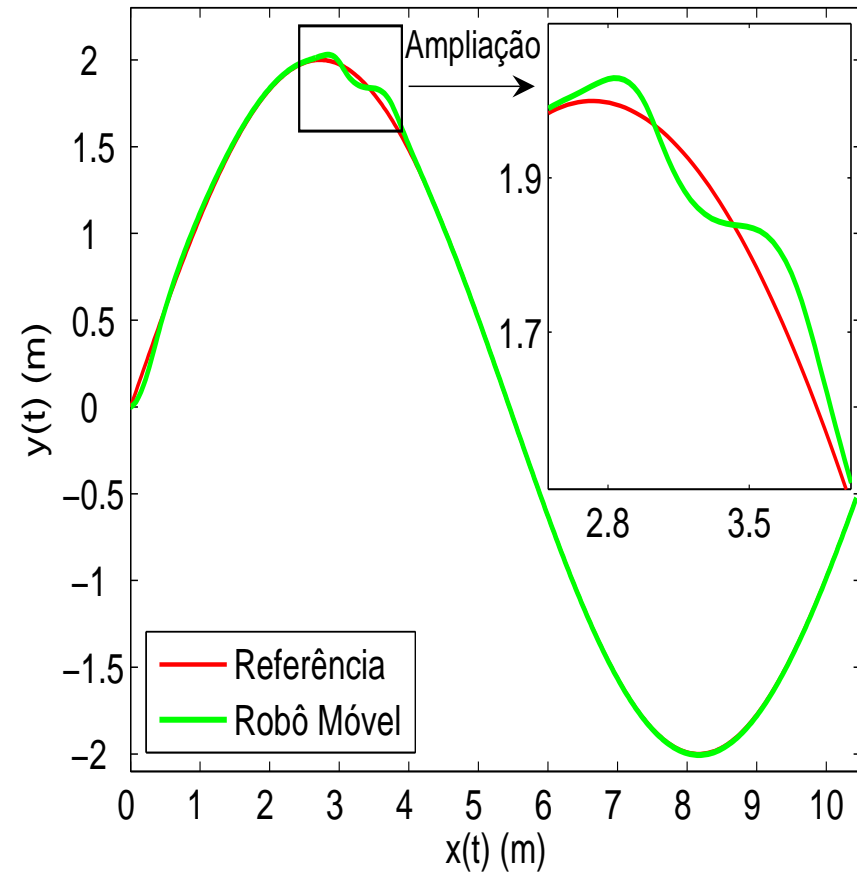
$$t_{12} = 1.3$$

$$k = 0.6$$

Controle via Teoria dos Jogos



Sem distúrbios



Com distúrbios

Controle via PD + TC

Controle via PD + TC

- Lei de controle

$$u_d = -[\theta_d - \theta_d^d]k_{p1} - [\dot{\theta}_d - \dot{\theta}_d^d]k_{d1}$$

$$u_e = -[\theta_e - \theta_e^d]k_{p2} - [\dot{\theta}_e - \dot{\theta}_e^d]k_{d2}$$

Controle via PD + TC

- Lei de controle

$$u_d = -[\theta_d - \theta_d^d]k_{p1} - [\dot{\theta}_d - \dot{\theta}_d^d]k_{d1}$$

$$u_e = -[\theta_e - \theta_e^d]k_{p2} - [\dot{\theta}_e - \dot{\theta}_e^d]k_{d2}$$

Selecionou $K_{p1} = K_{p2} = 10.9$ e $K_{d1} = K_{d2} = 5$

Controle via PD + TC

- **Lei de controle**

$$u_d = -[\theta_d - \theta_d^d]k_{p1} - [\dot{\theta}_d - \dot{\theta}_d^d]k_{d1}$$

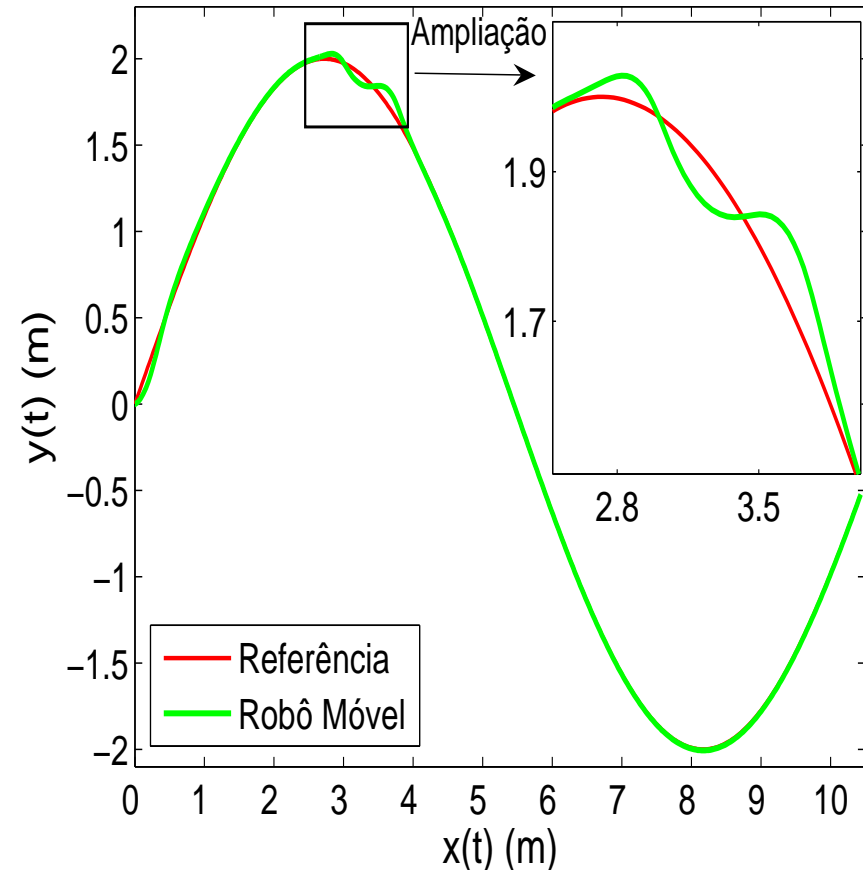
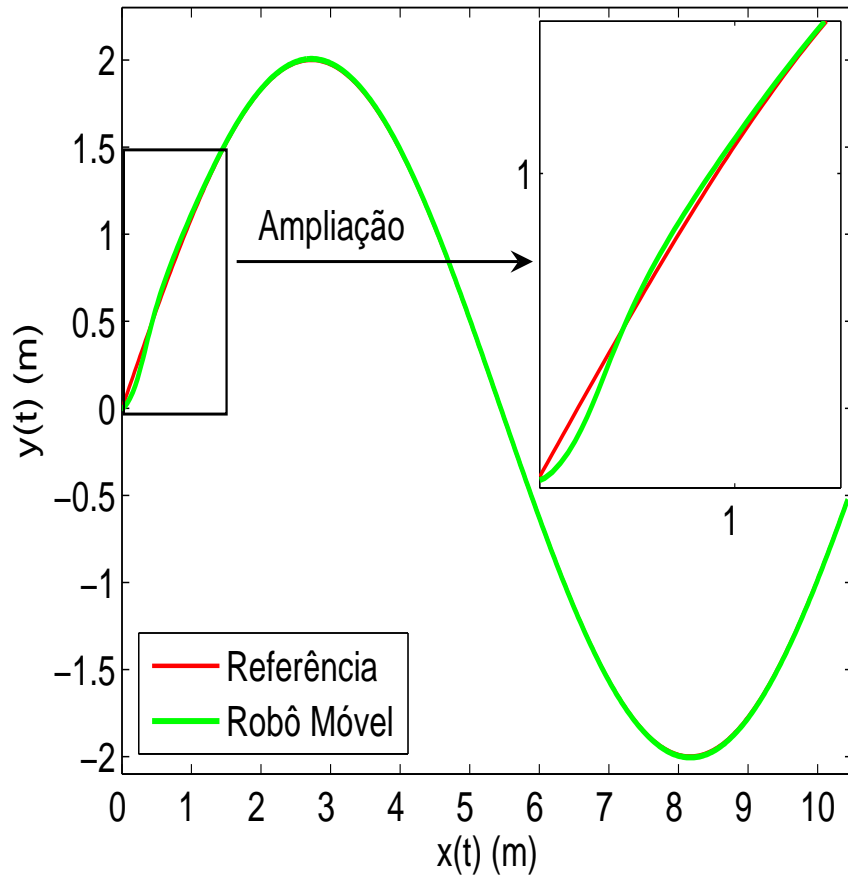
$$u_e = -[\theta_e - \theta_e^d]k_{p2} - [\dot{\theta}_e - \dot{\theta}_e^d]k_{d2}$$

Selecionou $K_{p1} = K_{p2} = 10.9$ e $K_{d1} = K_{d2} = 5$

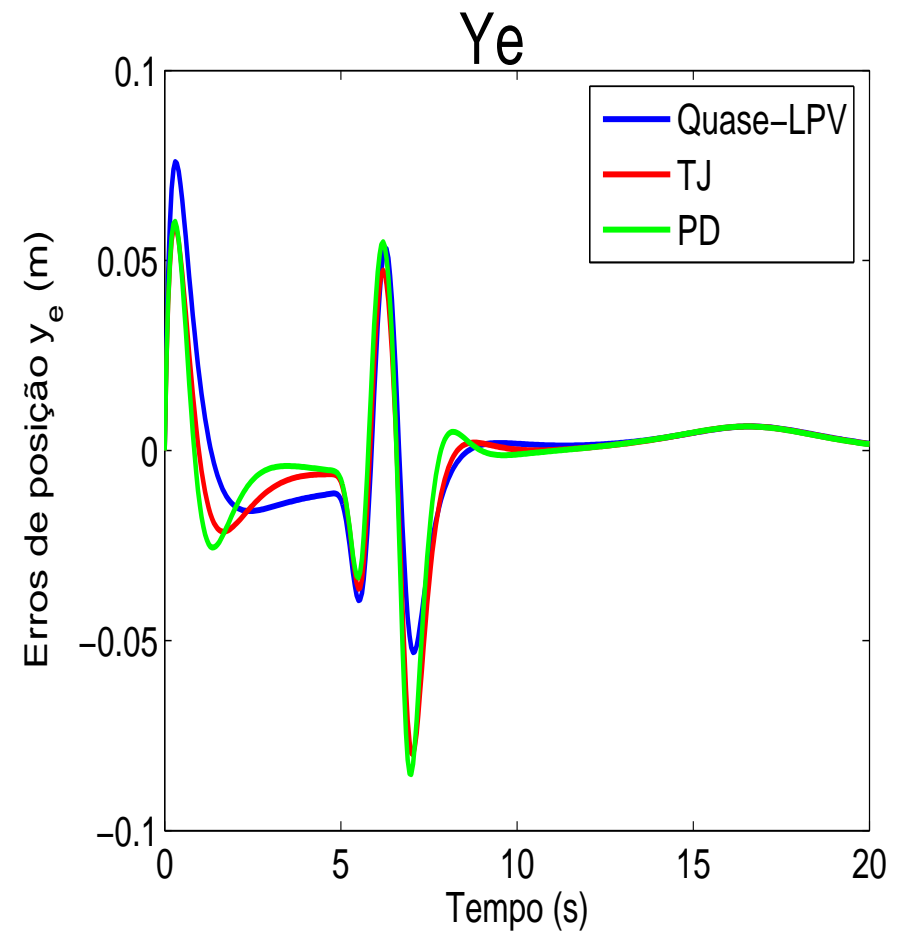
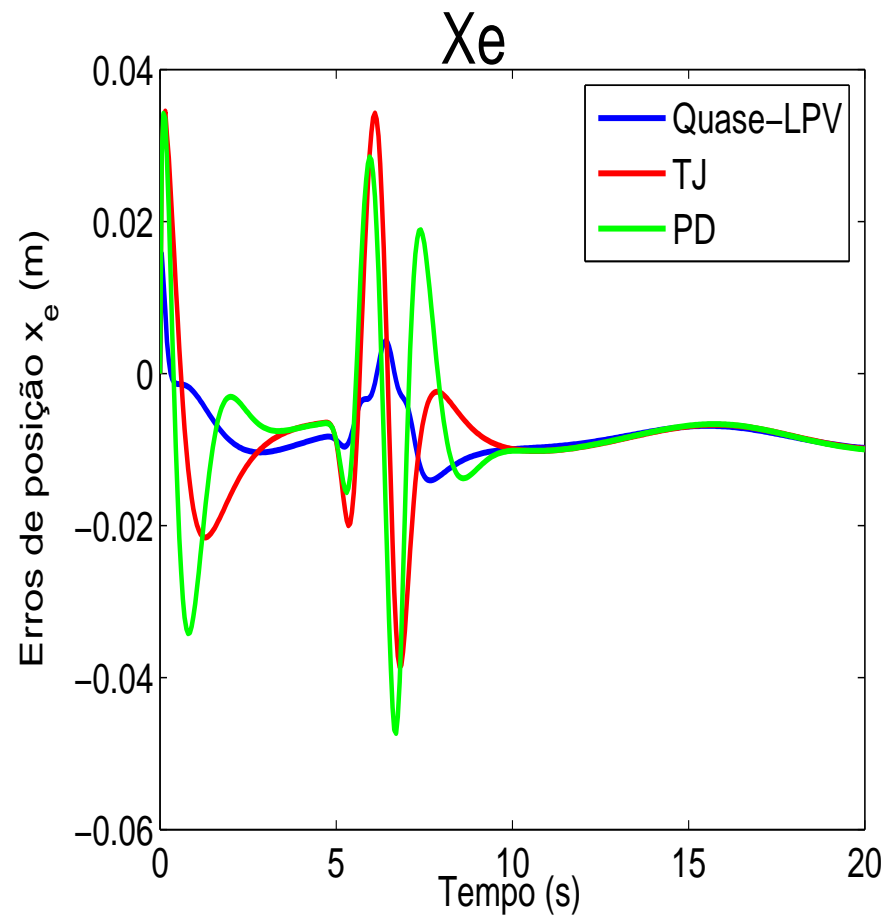
- **Torque calculado**

$$\tau = B^{-1}(\ddot{q}_2^d - A\dot{q}_2^d + u)$$

Controle via PD + TC



Estudo Comparativo



Estudo Comparativo

$$\mathcal{L}_2[e] = \left(\frac{1}{(t_r - t_0)} \int_{t_0}^{t_r} \|e\|_2^2 dt \right)^{\frac{1}{2}}$$

$$E[\tau] = \sum_{i=1}^2 \left(\int_{t_0}^{t_r} |\tau_i| dt \right)$$

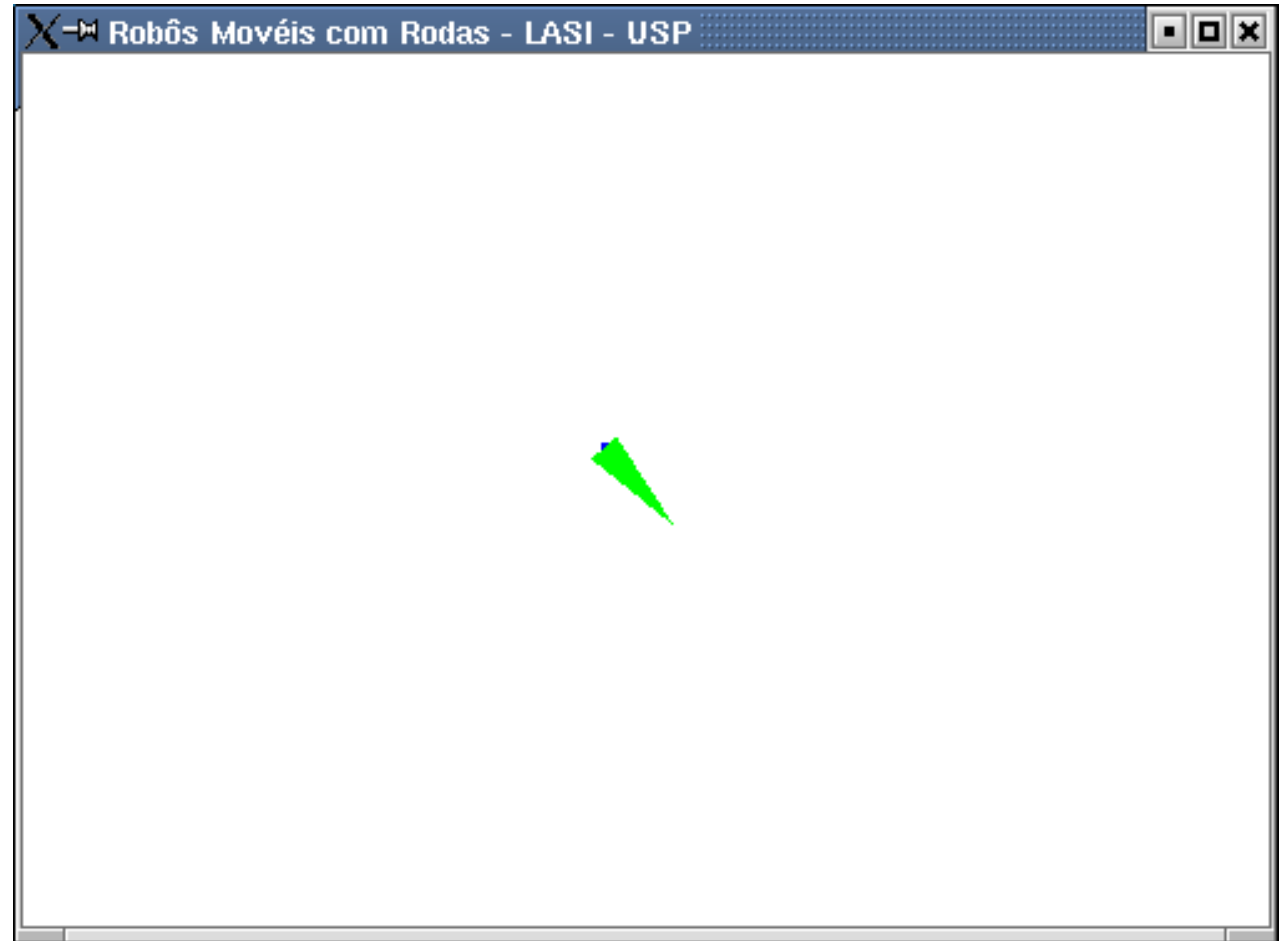
Estudo Comparativo

Controladores	γ	Distúrbios	$\mathcal{L}_2[e]$	$E[\tau]$
Quase-LPV	3.7	presente	0.53	283.9
		ausente	0.42	69.2
TJ	0.77	presente	0.55	286.5
		ausente	0.42	69.4
PD + TC	—	presente	0.58	288.8
		ausente	0.42	67.5

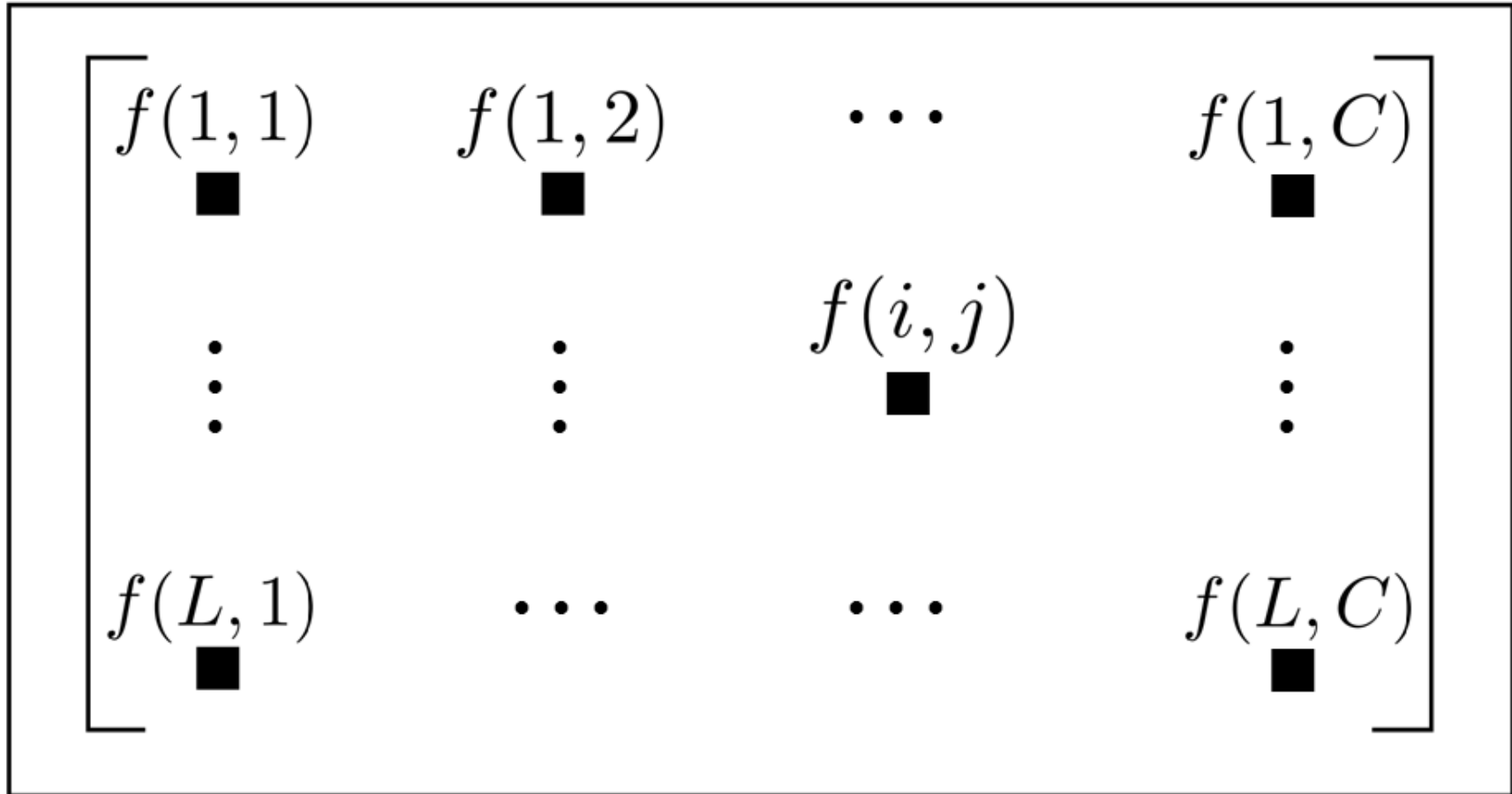
6- Implementação do módulo de visão



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Método dos Momentos

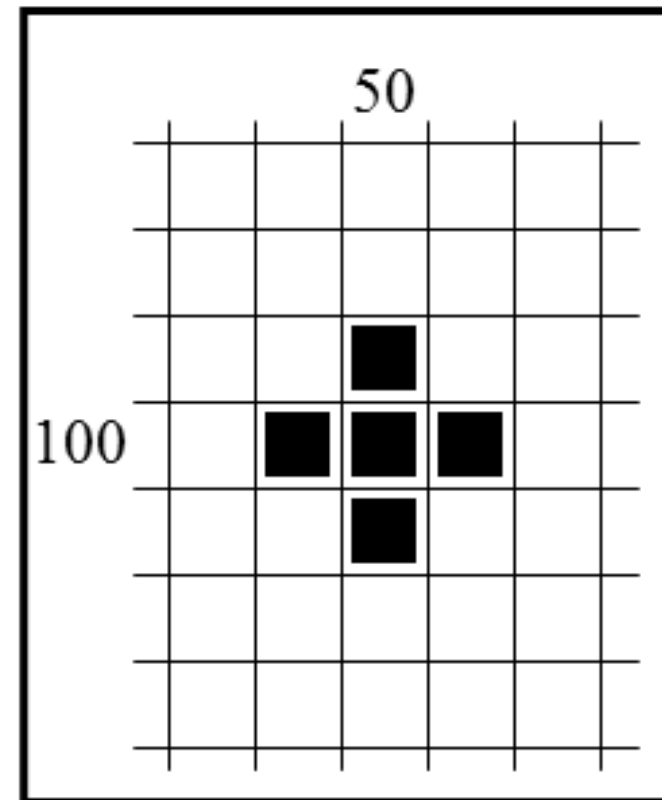
Imagens: $m_{pq} = \sum_i \sum_j i^p j^q f(i, j)$

6- Implementação do módulo de visão

Método dos Momentos

Imagens: $m_{pq} = \sum_i \sum_j i^p j^q f(i, j)$

- Exemplo



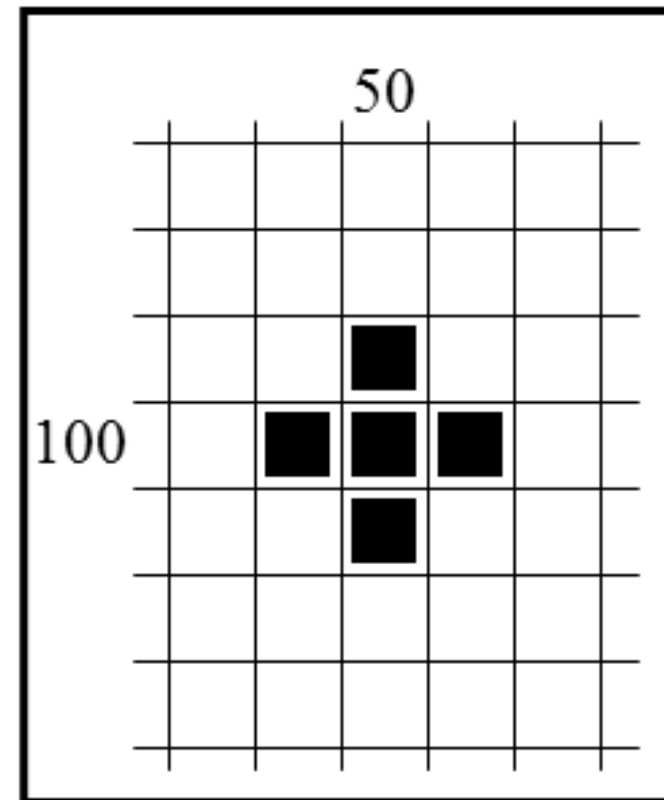
6- Implementação do módulo de visão

Método dos Momentos

Imagens: $m_{pq} = \sum_i \sum_j i^p j^q f(i, j)$

- Exemplo

$$f(i, j) = 10$$



6- Implementação do módulo de visão

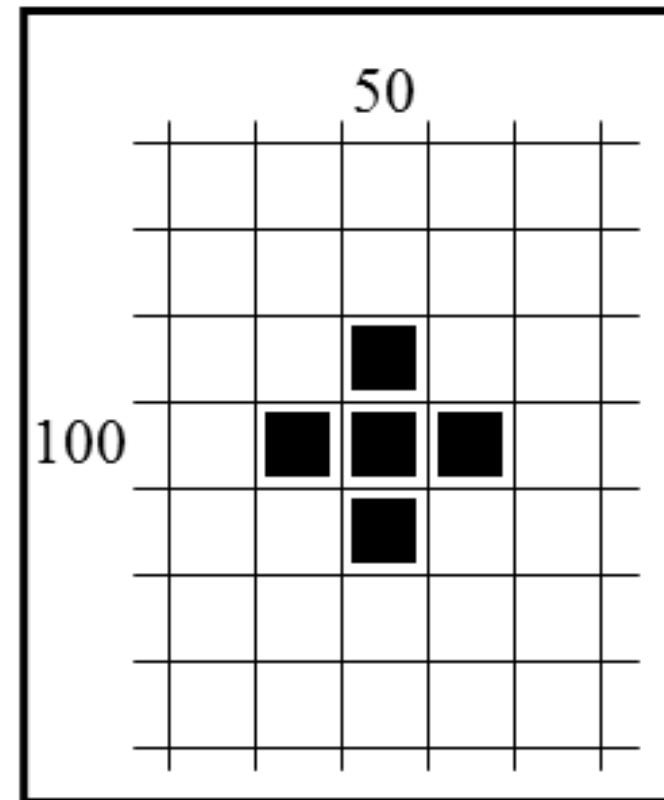
Método dos Momentos

Imagens: $m_{pq} = \sum_i \sum_j i^p j^q f(i, j)$

- Exemplo

$$f(i, j) = 10$$

$$m_{00} = 50$$



6- Implementação do módulo de visão

Método dos Momentos

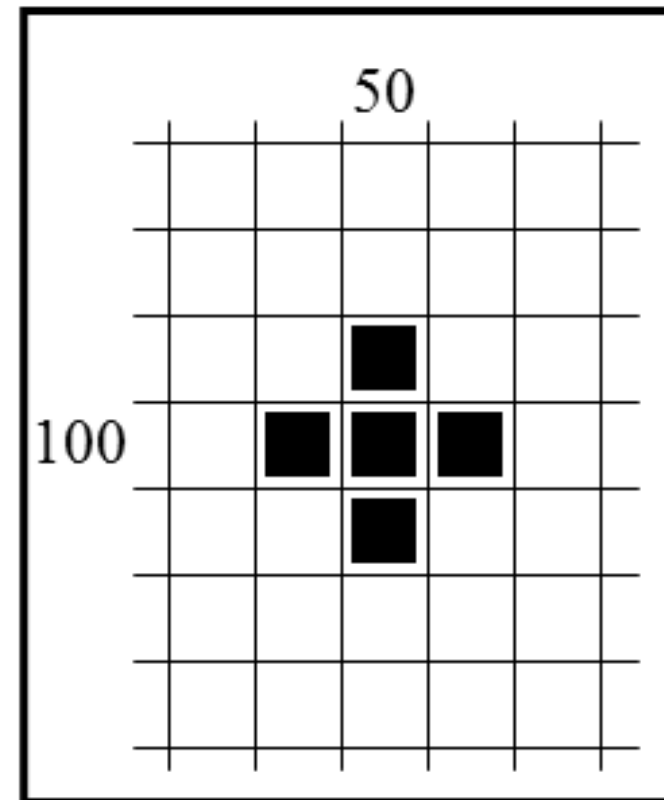
Imagens: $m_{pq} = \sum_i \sum_j i^p j^q f(i, j)$

- Exemplo

$$f(i, j) = 10$$

$$m_{00} = 50$$

$$\bar{i} = \frac{m_{10}}{m_{00}} = \frac{(99+300+101)*10}{50}$$



6- Implementação do módulo de visão

Método dos Momentos

Imagens: $m_{pq} = \sum_i \sum_j i^p j^q f(i, j)$

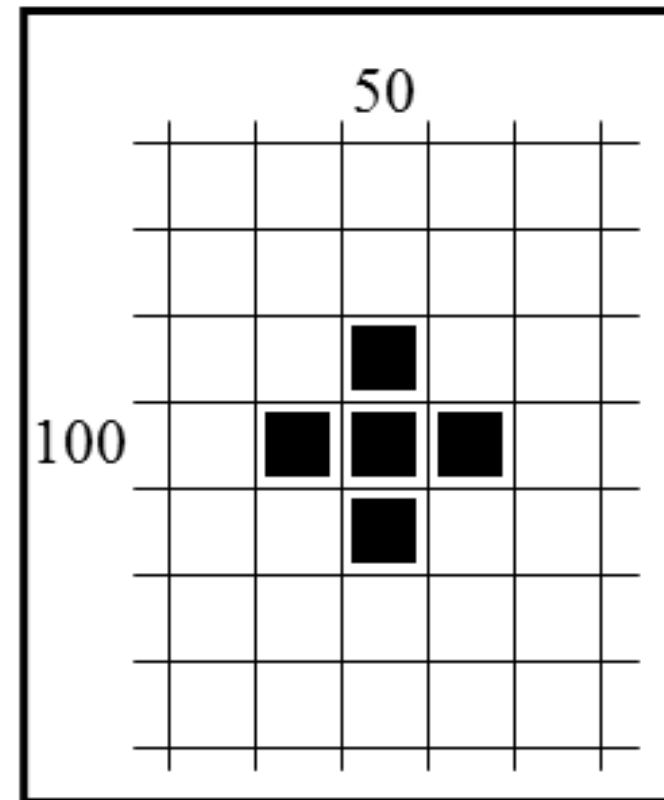
- Exemplo

$$f(i, j) = 10$$

$$m_{00} = 50$$

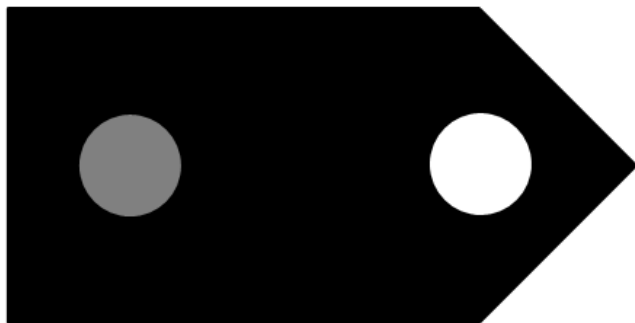
$$\bar{i} = \frac{m_{10}}{m_{00}} = \frac{(99+300+101)*10}{50}$$

$$\bar{j} = \frac{m_{01}}{m_{00}} = \frac{(49+150+51)*10}{50}$$



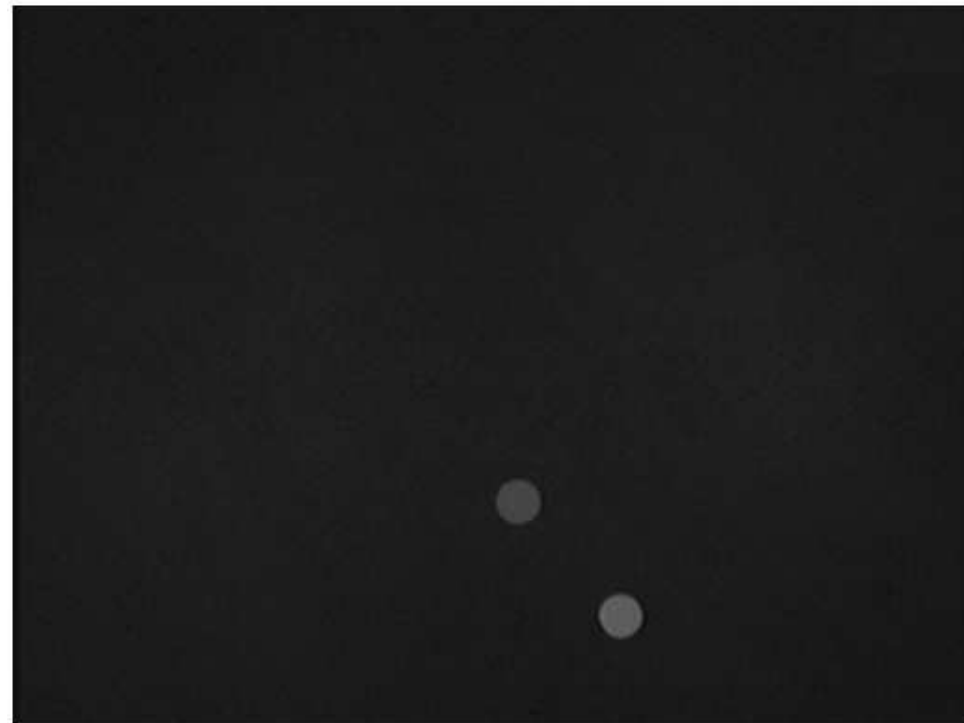
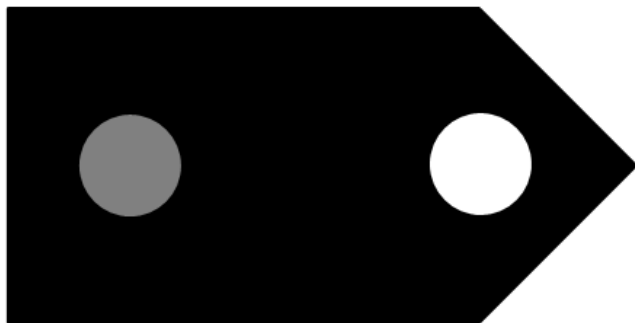
6- Implementação do módulo de visão

Método dos Momentos



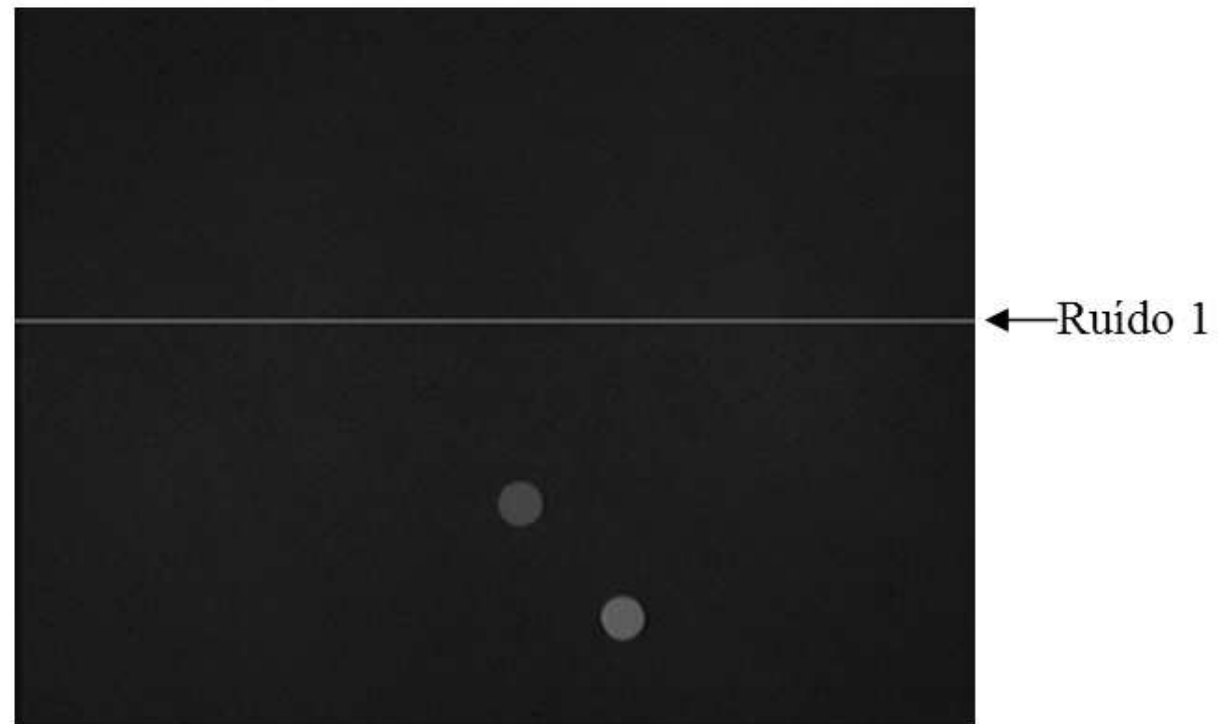
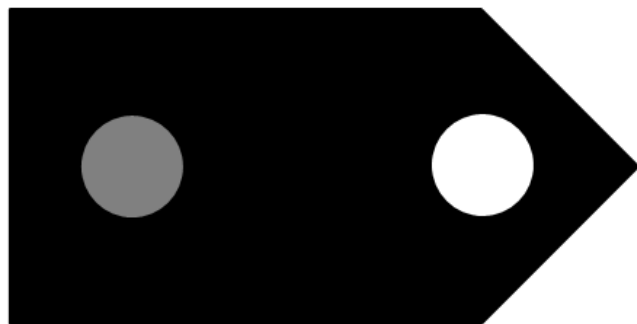
6- Implementação do módulo de visão

Método dos Momentos



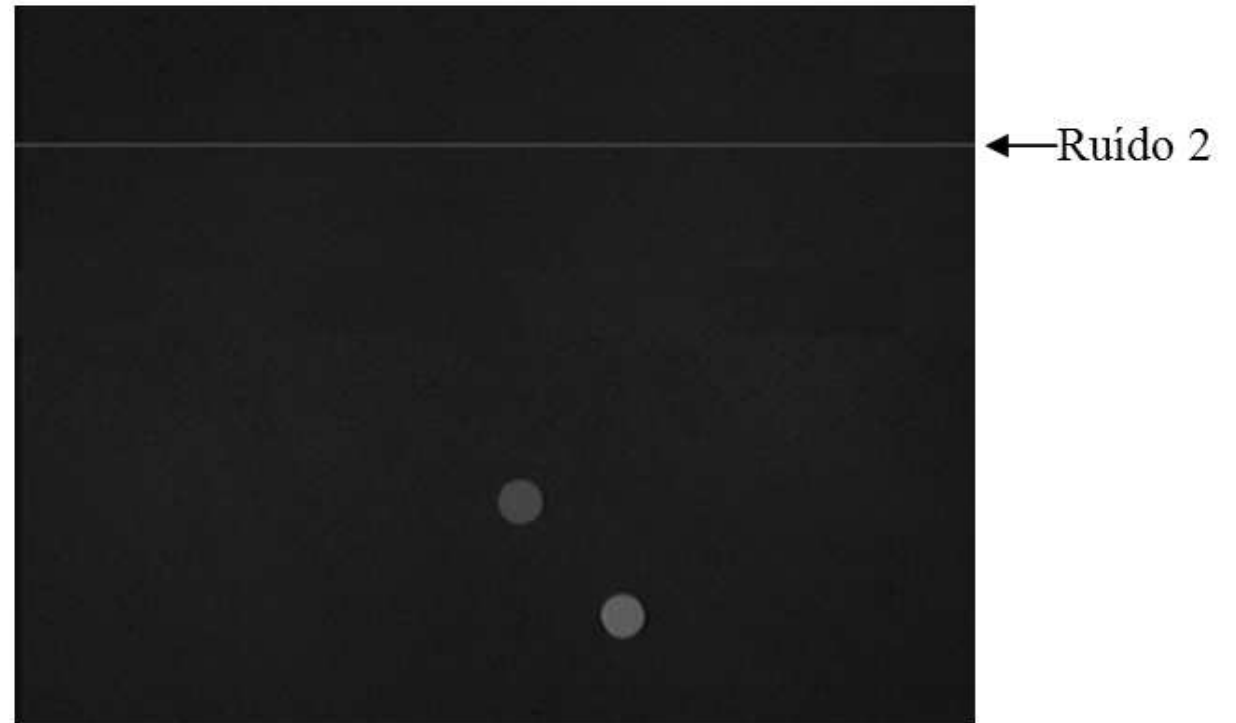
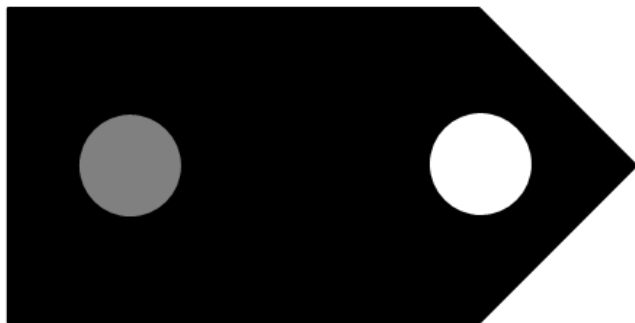
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Método dos Momentos



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Método dos Momentos



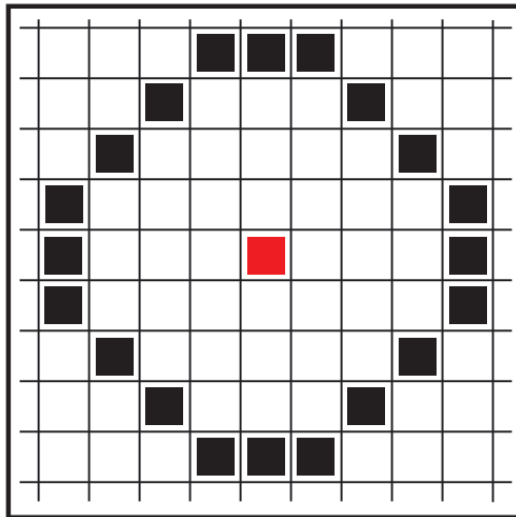
6- Implementação do módulo de visão

Método dos Momentos

	Sem Ruído				Ruído 1				Ruído 2			
	Tempo (ms)	Postura			Tempo (ms)	Postura			Tempo (ms)	Postura		
		i_o	j_o	$\alpha(^{\circ})$		i_o	j_o	$\alpha(^{\circ})$		i_o	j_o	$\alpha(^{\circ})$
Mom	0.40	166	170	312.5	0.41	166	170	66.6	0.42	106	165	290.6
Im	–	166	170	312.6	–	166	170	312.6	–	166	170	312.6

Método da THC

- Exemplo

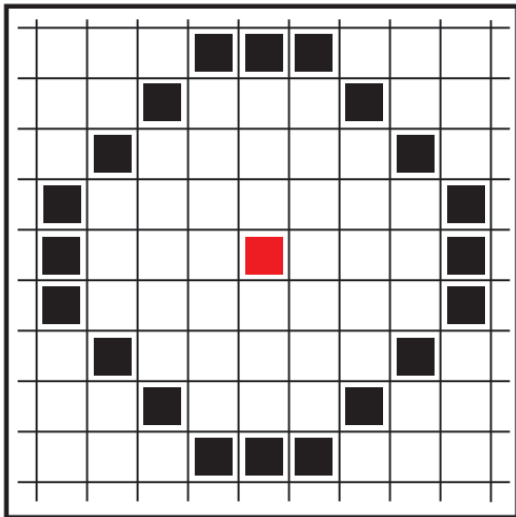


$L \times C$

6- Implementação do módulo de visão

Método da THC

- Exemplo



$L \times C$

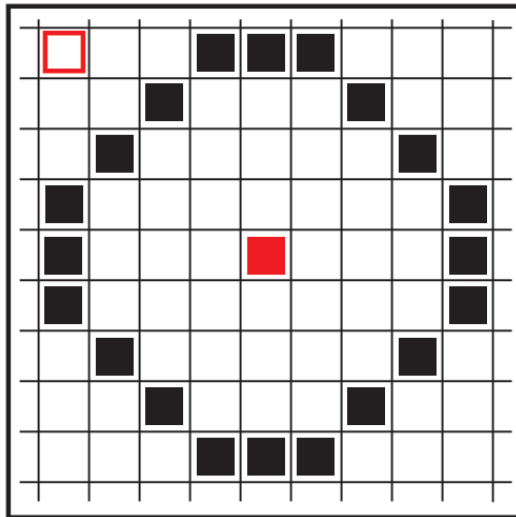
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$(L+2R) \times (C+2R)$

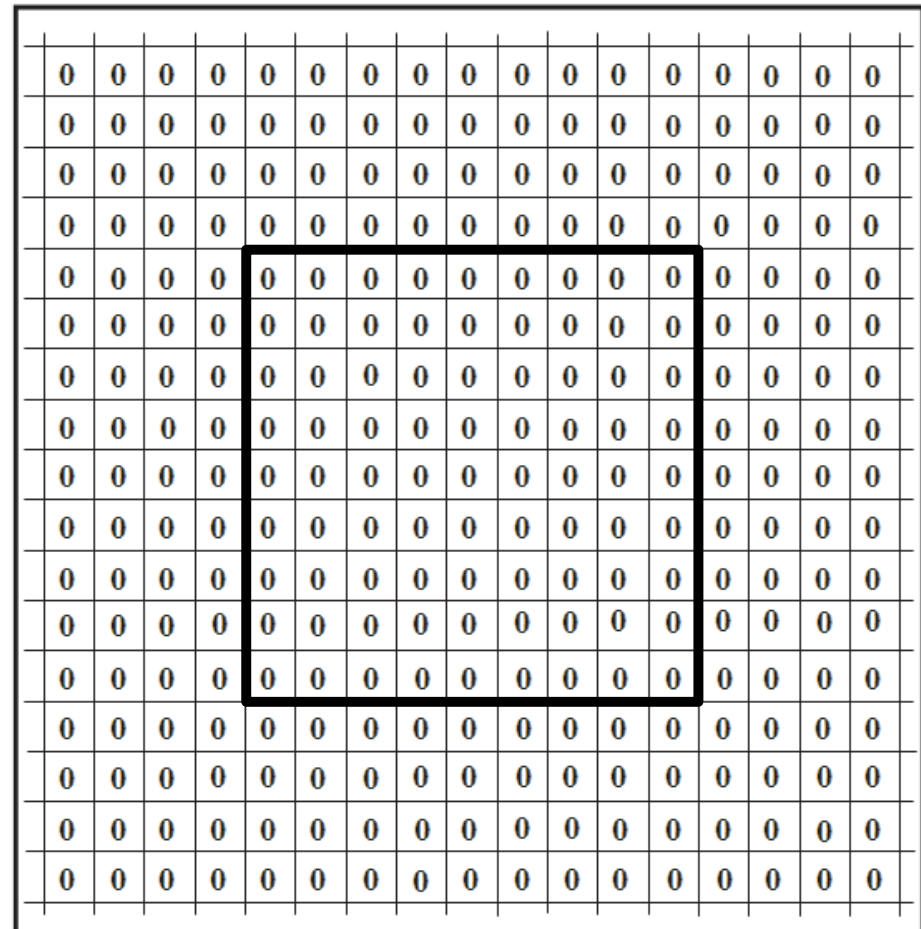
6- Implementação do módulo de visão

Método da THC

- Exemplo



$L \times C$

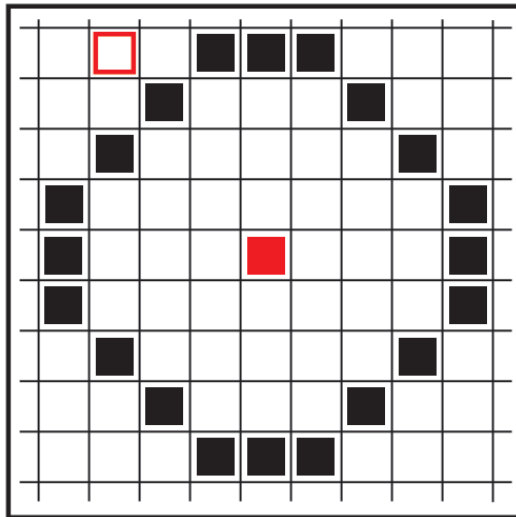


$(L+2R) \times (C+2R)$

6- Implementação do módulo de visão

Método da THC

- Exemplo



$L \times C$

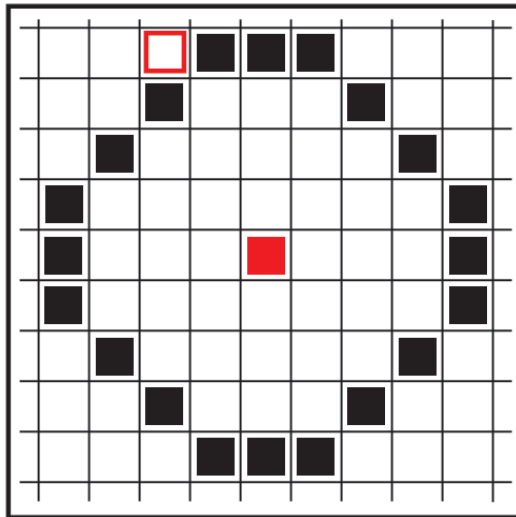
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$(L+2R) \times (C+2R)$

6- Implementação do módulo de visão

Método da THC

- Exemplo



$L \times C$

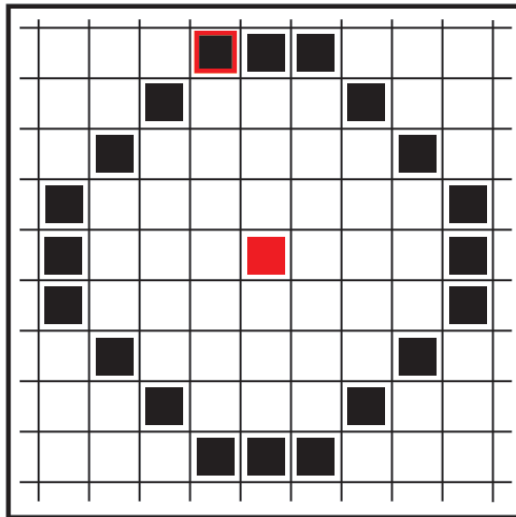
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$(L+2R) \times (C+2R)$

6- Implementação do módulo de visão

Método da THC

- Exemplo



$L \times C$

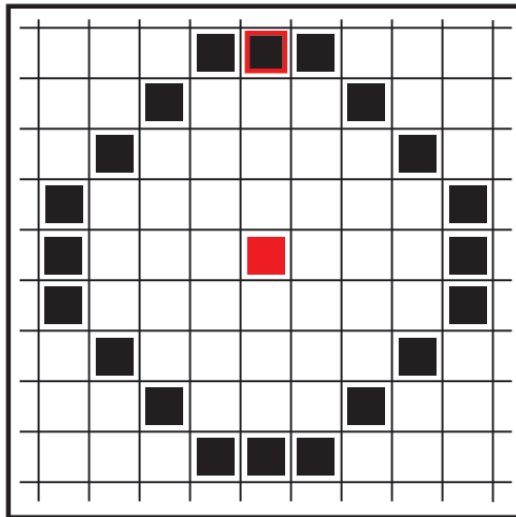
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0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

$(L+2R) \times (C+2R)$

6- Implementação do módulo de visão

Método da THC

- Exemplo



$L \times C$

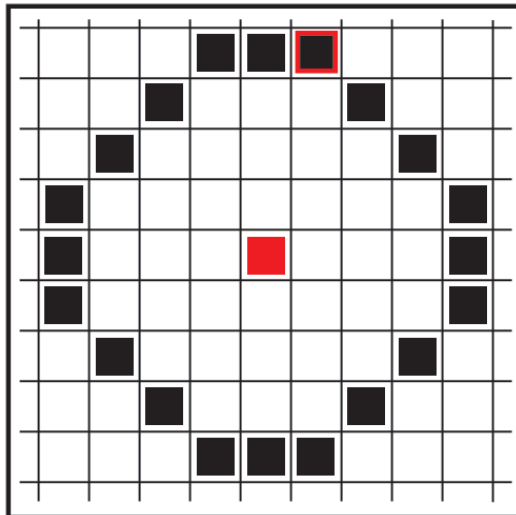
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0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

$(L+2R) \times (C+2R)$

6- Implementação do módulo de visão

Método da THC

- Exemplo



$L \times C$

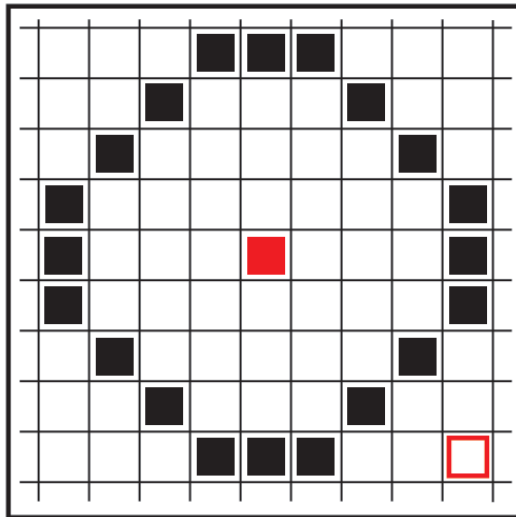
0	0	0	0	0	0	1	2	3	2	1	0	0	0	0	0	0
0	0	0	0	0	1	1	1	0	1	1	1	0	0	0	0	0
0	0	0	0	1	1	1	0	0	0	1	1	1	0	0	0	0
0	0	0	1	1	1	0	0	0	0	0	1	1	1	0	0	0
0	0	0	1	1	1	0	0	0	0	0	1	1	1	0	0	0
0	0	0	1	1	1	0	0	0	0	0	1	1	1	0	0	0
0	0	0	0	1	1	1	0	0	0	1	1	1	0	0	0	0
0	0	0	0	0	1	1	1	0	1	1	1	0	0	0	0	0
0	0	0	0	0	0	1	2	3	2	1	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

$(L+2R) \times (C+2R)$

6- Implementação do módulo de visão

Método da THC

- Exemplo



$L \times C$

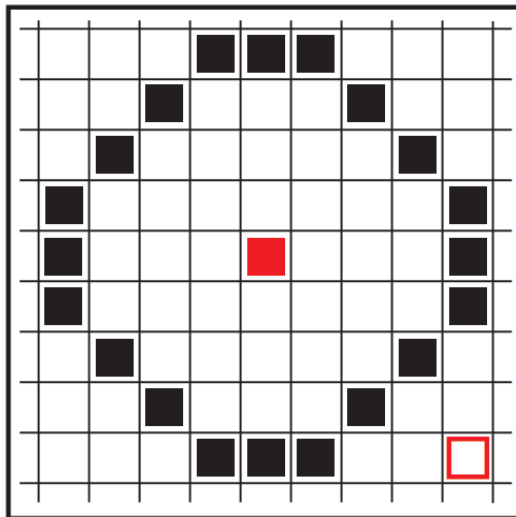
0	0	0	0	0	0	1	2	3	2	1	0	0	0	0	0
0	0	0	0	0	2	2	2	0	2	2	2	0	0	0	0
0	0	0	0	3	2	2	0	2	0	2	2	3	0	0	0
0	0	0	4	2	2	0	2	0	2	0	2	2	4	0	0
0	0	3	2	2	2	2	0	2	0	2	2	2	2	3	0
0	2	2	2	2	2	2	2	0	2	2	2	2	2	2	2
1	2	2	0	2	2	4	2	2	2	4	2	2	0	2	2
2	2	0	2	0	2	2	6	4	6	2	2	0	2	0	2
3	0	2	0	2	0	2	4	20	4	2	0	2	0	2	0
2	2	0	2	0	2	2	6	4	6	2	2	0	2	0	2
1	2	2	0	2	2	4	2	2	2	4	2	2	0	2	2
0	2	2	2	2	2	2	2	0	2	2	2	2	2	2	2
0	0	3	2	2	2	2	0	2	0	2	2	2	2	3	0
0	0	0	4	2	2	0	2	0	2	0	2	2	4	0	0
0	0	0	0	3	2	2	0	2	0	2	2	3	0	0	0
0	0	0	0	0	2	2	2	0	2	2	2	0	0	0	0
0	0	0	0	0	0	1	2	3	2	1	0	0	0	0	0

$(L+2R) \times (C+2R)$

6- Implementação do módulo de visão

Método da THC

- Exemplo



$L \times C$

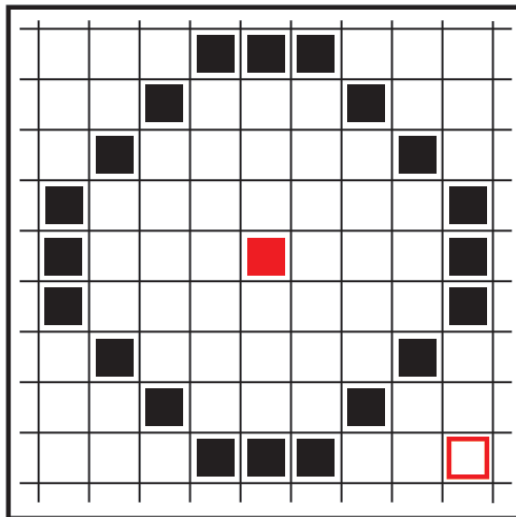
0	0	0	0	0	0	1	2	3	2	1	0	0	0	0	0
0	0	0	0	0	2	2	2	0	2	2	2	0	0	0	0
0	0	0	0	3	2	2	0	2	0	2	2	3	0	0	0
0	0	0	4	2	2	0	2	0	2	0	2	2	4	0	0
0	0	3	2	2	2	2	0	2	0	2	2	2	2	3	0
0	2	2	2	2	2	2	2	0	2	2	2	2	2	2	2
1	2	2	0	2	2	4	2	2	2	4	2	2	0	2	2
2	2	0	2	0	2	2	6	4	6	2	2	0	2	0	2
3	0	2	0	2	0	2	4	20	4	2	0	2	0	2	3
2	2	0	2	0	2	2	6	4	6	2	2	0	2	0	2
1	2	2	0	2	2	4	2	2	2	4	2	2	0	2	2
0	2	2	2	2	2	2	2	0	2	2	2	2	2	2	2
0	0	3	2	2	2	2	0	2	0	2	2	2	2	3	0
0	0	0	4	2	2	0	2	0	2	0	2	2	4	0	0
0	0	0	0	3	2	2	0	2	0	2	2	3	0	0	0
0	0	0	0	0	2	2	2	0	2	2	2	0	0	0	0
0	0	0	0	0	0	1	2	3	2	1	0	0	0	0	0

$(L+2R) \times (C+2R)$

6- Implementação do módulo de visão

Método da THC

- Exemplo



$L \times C$

$$f_{max}(i, j) = 20$$

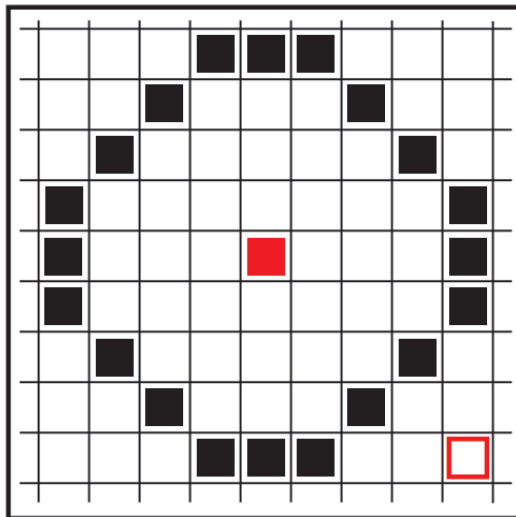
0	0	0	0	0	0	1	2	3	2	1	0	0	0	0	0
0	0	0	0	0	2	2	2	0	2	2	2	0	0	0	0
0	0	0	0	3	2	2	0	2	0	2	2	3	0	0	0
0	0	0	4	2	2	0	2	0	2	0	2	2	4	0	0
0	0	3	2	2	2	2	0	2	0	2	2	2	2	3	0
0	2	2	2	2	2	2	2	0	2	2	2	2	2	2	2
1	2	2	0	2	2	4	2	2	2	4	2	2	0	2	2
2	2	0	2	0	2	2	6	4	6	2	2	0	2	0	2
3	0	2	0	2	0	2	4	20	4	2	0	2	0	2	3
2	2	0	2	0	2	2	6	4	6	2	2	0	2	0	2
1	2	2	0	2	2	4	2	2	2	4	2	2	0	2	2
0	2	2	2	2	2	2	2	0	2	2	2	2	2	2	2
0	0	3	2	2	2	2	0	2	0	2	2	2	2	3	0
0	0	0	4	2	2	0	2	0	2	0	2	2	4	0	0
0	0	0	0	3	2	2	0	2	0	2	2	3	0	0	0
0	0	0	0	0	2	2	2	0	2	2	2	0	0	0	0
0	0	0	0	0	0	1	2	3	2	1	0	0	0	0	0

$(L+2R) \times (C+2R)$

6- Implementação do módulo de visão

Método da THC

- Exemplo



$L \times C$

$$f_{max}(i, j) = 20$$

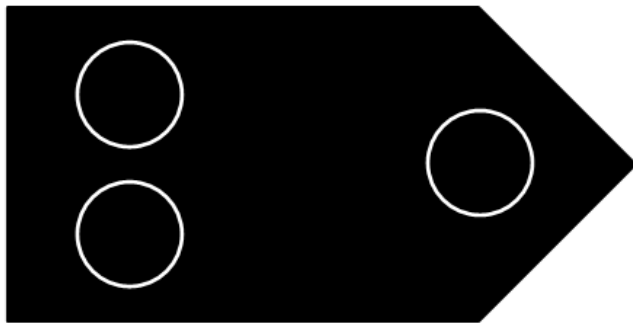
$$\therefore \begin{aligned} \bar{i} &= i - R \\ \bar{j} &= j - R \end{aligned}$$

0	0	0	0	0	0	1	2	3	2	1	0	0	0	0	0
0	0	0	0	0	2	2	2	0	2	2	2	0	0	0	0
0	0	0	0	3	2	2	0	2	0	2	2	3	0	0	0
0	0	0	4	2	2	0	2	0	2	0	2	2	4	0	0
0	0	3	2	2	2	2	0	2	0	2	2	2	2	3	0
0	2	2	2	2	2	2	2	0	2	2	2	2	2	2	0
1	2	2	0	2	2	4	2	2	2	4	2	2	0	2	2
2	2	0	2	0	2	2	6	4	6	2	2	0	2	0	2
3	0	2	0	2	0	2	4	20	4	2	0	2	0	2	0
2	2	0	2	0	2	2	6	4	6	2	2	0	2	0	2
1	2	2	0	2	2	4	2	2	2	4	2	2	0	2	2
0	2	2	2	2	2	2	2	0	2	2	2	2	2	2	0
0	0	3	2	2	2	2	0	2	0	2	2	2	2	3	0
0	0	0	4	2	2	0	2	0	2	0	2	2	4	0	0
0	0	0	0	3	2	2	0	2	0	2	2	3	0	0	0
0	0	0	0	0	2	2	2	0	2	2	2	0	0	0	0
0	0	0	0	0	0	1	2	3	2	1	0	0	0	0	0

$(L+2R) \times (C+2R)$

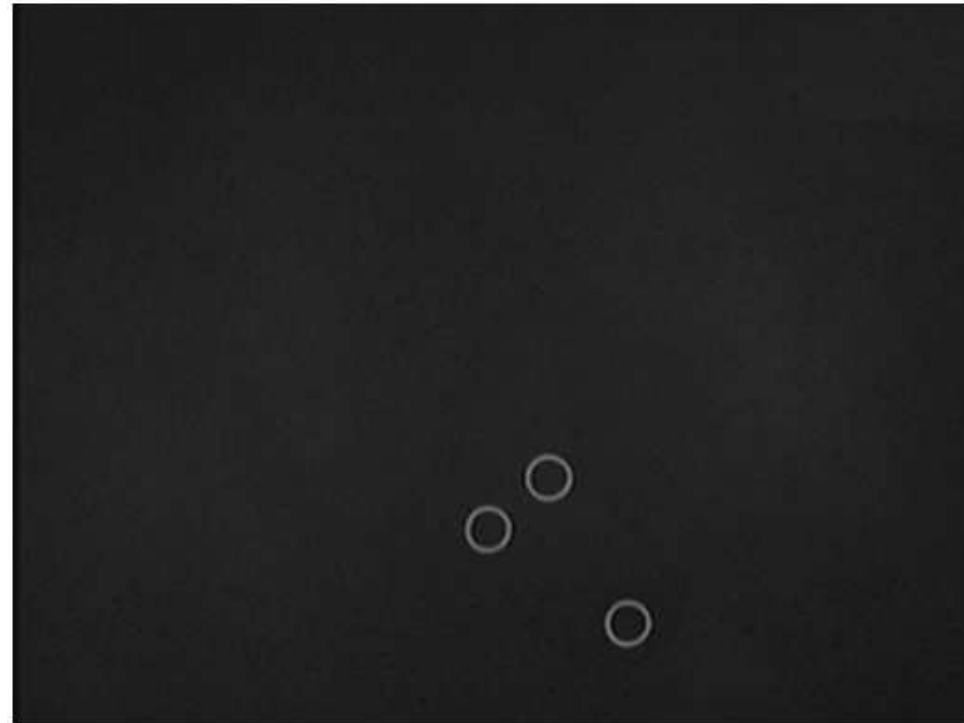
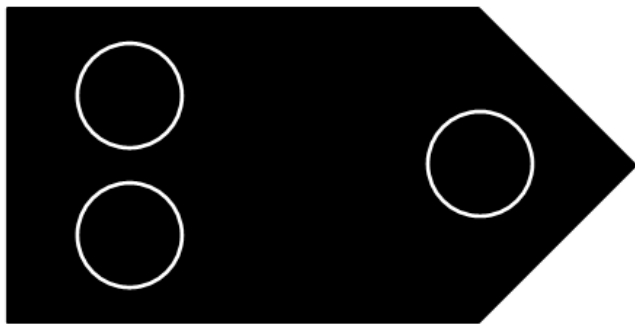
6- Implementação do módulo de visão

Método da THC



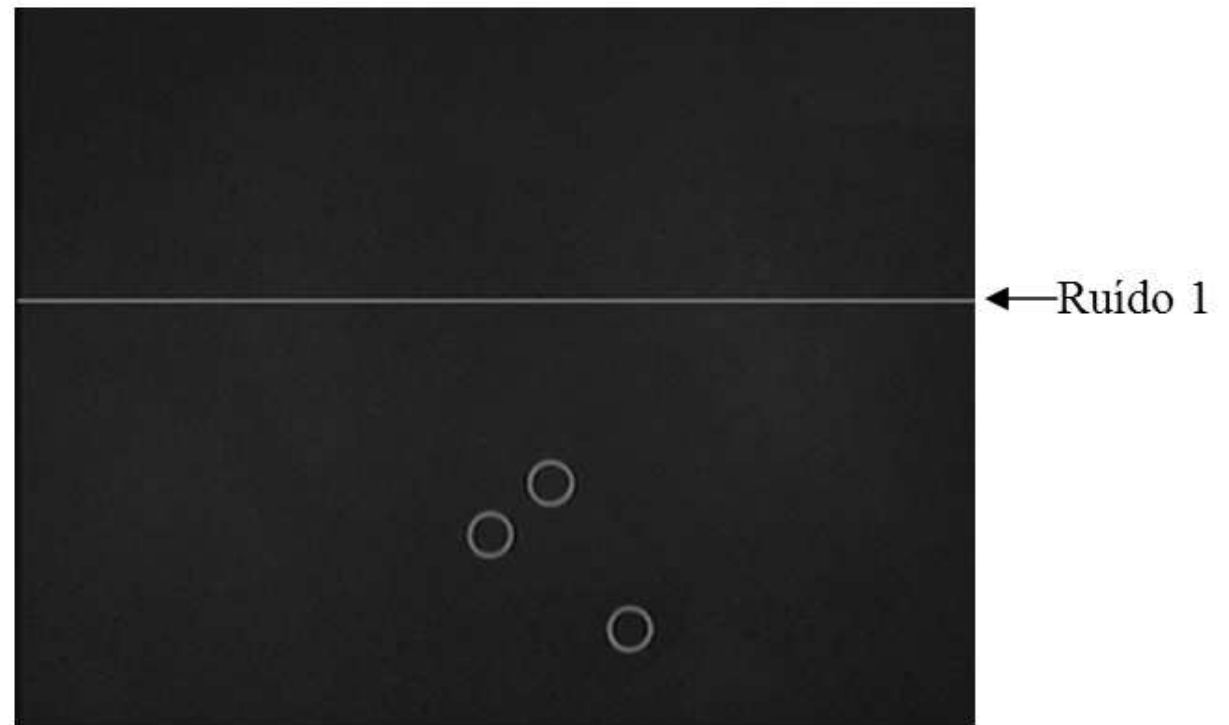
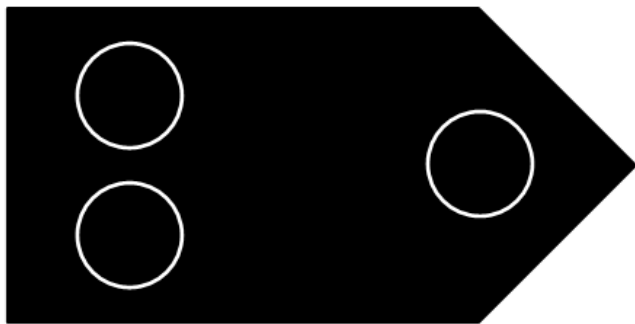
6- Implementação do módulo de visão

Método da THC



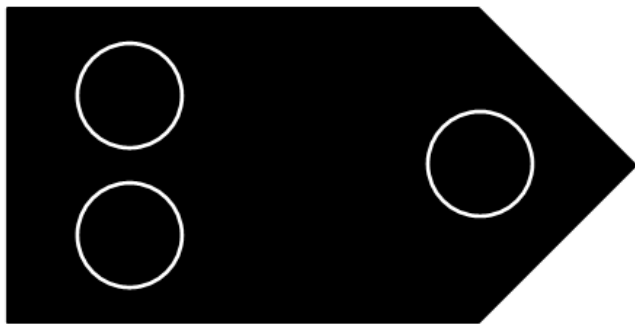
6- Implementação do módulo de visão

Método da THC



6- Implementação do módulo de visão

Método da THC



6- Implementação do módulo de visão

Método da THC

	Sem Ruído				Ruído 1				Ruído 2			
	Tempo (ms)	Postura			Tempo (ms)	Postura			Tempo (ms)	Postura		
		i_o	j_o	$\alpha(^{\circ})$		i_o	j_o	$\alpha(^{\circ})$		i_o	j_o	$\alpha(^{\circ})$
THC	1.35	165	168	312.8	1.64	165	168	312.8	1.71	165	168	312.8
Im	–	165	168	312.8	–	165	168	312.8	–	165	168	312.8

Conclusão

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- Controle: -Controladores robusto para RMRs
-Estudo comparativo

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- Localização: -Métodos: Momentos \times THC

Trabalho futuro

Conclusão

- Controle: -Controladores robusto para RMRs
-Estudo comparativo
- Localização: -Métodos: Momentos \times THC

Trabalho futuro

- Implementar controladores:
 - Robô: SmartROB ou LasiRob
 - Localização: Visão computacional (THC)
 - Controle: Computador
 - Comunicação: Porta serial