<u>**AUTOEBALUAZIOA: EMAITZAK**</u>

TEORIA

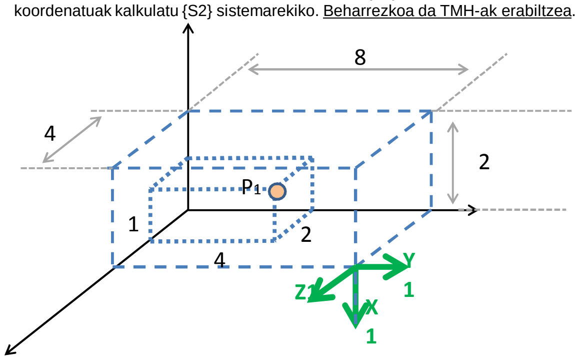
1) Robot-beso baten ezaugarri ESTATIKOAK aipatu. (**0.5 puntu**)
   1)Askatasun-gradua
   2)Lan-bolumena
   3)Irisgarritasuna
   4)Maniobragarritasuna
   5)Mugikortasuna

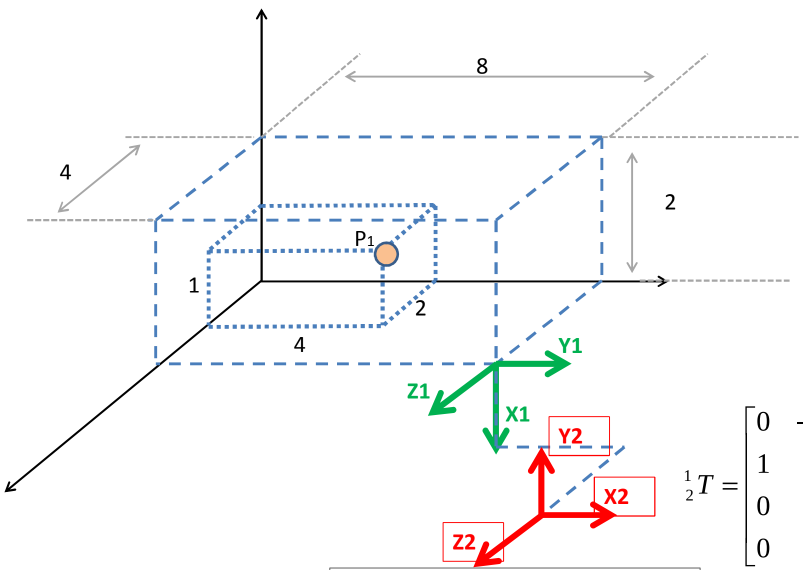
2) **ENKODERRA**, barruko edo kanpoko sentsore bat da? Zer neurtzen du? (**0.5 puntu**)

Barneko sentsore bat da eta posizioa neurtzen du

3) Irudian {S1} sistemaren eta P1 puntuaren lokalizazioa adierazten da. Jakinik {S1} eta {S2} sistemek erlazionatzen dituen TMH ondokoa dela {S2} sistema irudikatu eta P1 puntuaren koordenatuak kalkulatu {S2} sistemarekiko. <u>Beharrezkoa da TMH-ak erabiltzea</u>. (**1.5 puntu**)

$$ {}^{1}_{2}T = \begin{bmatrix} 0 & -1 & 0 & 1 \\ 1 & 0 & 0 & 2 \\ 0 & 0 & 1 & 3 \\ 0 & 0 & 0 & 1 \end{bmatrix} $$





$$ {}^{1}_{2}T = \begin{bmatrix} 0 & -1 & 0 & 1 \\ 1 & 0 & 0 & 2 \\ 0 & 0 & 1 & 3 \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

1) Traslazioa (1,2,3)
2) Biraketa R(Z, 90º)

P1 puntuaren koordenatuak 1 sistemarekiko : $^{1}P1 = [-1,-4,-2]$

P1 puntuaren koordenatuak 2 sistemarekiko:

$$^{2}P1 \Rightarrow {}^{2}P1 = {}^{2}_{1}T \cdot {}^{1}P1$$

Aderantzizko matrizea kalkulatu behar da

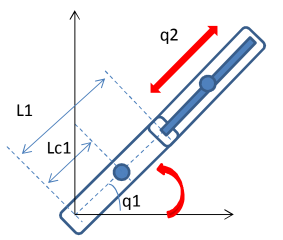
$$^{1}_{2}T = \begin{bmatrix} 0 & -1 & 0 & 1 \\ 1 & 0 & 0 & 2 \\ 0 & 0 & 1 & 3 \\ 0 & 0 & 0 & 1 \end{bmatrix} \qquad {}^{2}_{1}T = \begin{bmatrix} 0 & 1 & 0 & -2 \\ -1 & 0 & 0 & 1 \\ 0 & 0 & 1 & -3 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$^{2}P1 = {}^{2}_{1}T\,{}^{1}P1 = \begin{bmatrix} 0 & 1 & 0 & -2 \\ -1 & 0 & 0 & 1 \\ 0 & 0 & 1 & -3 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} -1 \\ -4 \\ -2 \\ 1 \end{bmatrix} = \begin{bmatrix} -6 \\ 2 \\ -2 \\ 1 \end{bmatrix}$$

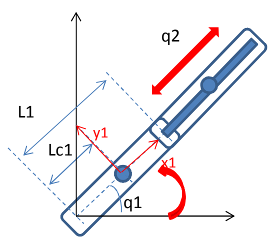
P1 puntuaren koordenatuak 2 sistemarekiko: $^{2}P1 = [-6,2,-5]$

1 ARIKETA

Irudiko robota 2 askatasun-gradu ditu, lehenengoa errotazionala eta bigarrena PRISMATIKOA. Energi balantzean oinarrituz, LAGRANGETARRA kalkulatu.



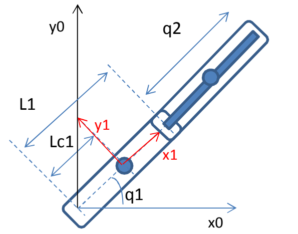
D-Hen erreferentzi sistemen esleipena_1. kate maila



1 pausua: energia zinetikoaren kalkulua (K)

Kate-maila 1: $K_1 = \frac{1}{2} m_1 v_1^T v_1 + \frac{1}{2} \omega_1^T I_1 \omega_1$

Lehenengo kate-mailaren TMH a kalkulatzen dugu:



	θi	di	ai	αi
1	q1	0	L_{c1}	0º

$$ {}^0_1A = \begin{bmatrix} Cq1 & -Sq1 & 0 & L_{c1}Cq1 \\ Sq1 & Cq1 & 0 & L_{c1}Sq1 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad \begin{matrix} \rightarrow x = L_{c1}Cq1 \\ \rightarrow y = L_{c1}Sq1 \\ \rightarrow z = 0 \end{matrix} $$

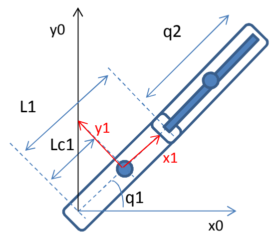
Jacobtarra erabiliz:

1 kate-mailaren abiadura lineala

$$ J = \begin{bmatrix} \frac{\partial x}{\partial q_1} & \frac{\partial x}{\partial q_2} & \frac{\partial x}{\partial q_3} \\ \frac{\partial y}{\partial q_1} & \frac{\partial y}{\partial q_2} & \frac{\partial y}{\partial q_3} \\ \frac{\partial z}{\partial q_1} & \frac{\partial z}{\partial q_2} & \frac{\partial z}{\partial q_3} \end{bmatrix} = \begin{bmatrix} -L_{c1}Sq1 & 0 & 0 \\ L_{c1}Cq1 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \Rightarrow v_1 = \begin{bmatrix} -L_{c1}Sq1 & 0 & 0 \\ L_{c1}Cq1 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} \dot{q}1 \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} -L_{c1}Sq1\,\dot{q}1 \\ L_{c1}Cq1\,\dot{q}1 \\ 0 \end{bmatrix} $$

1 pausua: energia zinetikoaren kalkulua (K)

Energia zinetikoa $K_1 = \frac{1}{2} m_1 v_1^T v_1 + \frac{1}{2} \omega_1^T I_1 \omega_1$



$$ v_1^T v_1 = \begin{bmatrix} -L_{c1}Sq1\,\dot{q}1 & L_{c1}Cq1\,\dot{q}1 & 0 \end{bmatrix} \begin{bmatrix} -L_{c1}Sq1\,\dot{q}1 \\ L_{c1}Cq1\,\dot{q}1 \\ 0 \end{bmatrix} = L_{c1}^2\,\dot{q}_1^2 $$

1 kate-mailaren abiadura **angeluarra** :

$$ \vec{w}_1 = \dot{q}_1 \, \vec{z}_0 $$

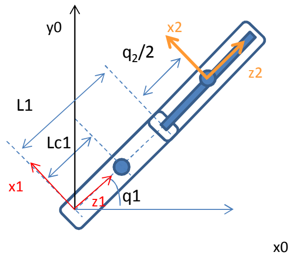
1 kate-mailaren energia zinetikoa :

$$ \boxed{K_1 = \frac{1}{2} m_1 L_{c1}^2 \dot{q}_1^2 + \frac{1}{2} I_1 \dot{q}_1^2} $$

1 pausua: energia zinetikoaren kalkulua (K)

2 kate-maila :

$$K_2 = \frac{1}{2} m_2 v_2^T v_2 + \frac{1}{2} \omega_2^T I_2 \omega_2$$



Bigarren kate-mailaren TMH a kalkulatzen dugu:

$$ {}^0_2A = {}^0_1A\,{}^1_2A = \begin{bmatrix} -Sq1 & 0 & Cq1 & 0 \\ Cq1 & 0 & Sq1 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & L_1 + {q_2}/{2} \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

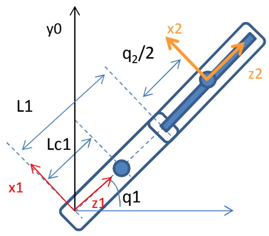
	θi	di	ai	αi
1	Q1+90	0	0	90º
2	0	$L_1 + q_2/2$	0	0º

$$ {}^0_2A = {}^0_1A\,{}^1_2A = \begin{bmatrix} -Sq1 & 0 & Cq1 & Cq1(L_1 + {q_2}/{2}) \\ Cq1 & 0 & Sq1 & Sq1(L_1 + {q_2}/{2}) \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{matrix} =x \\ =y \\ =z \\ \\ \end{matrix} $$

1 pausua: energia zinetikoaren kalkulua (K)

Kate-maila 2: $K_2 = \frac{1}{2} m_2 v_2^T v_2 + \frac{1}{2} \omega_2^T I_2 \omega_2$

2 kate-mailaren TMH a kalkulatzen dugu:



	θi	di	ai	αi
1	Q1+90	0	0	90º
2	0	$L_1 + q_2/2$	0	0º

$$x = Cq1(L_1 + {q_2}/{2})$$

$$y = Sq1(L_1 + {q_2}/{2})$$

$$z = 0$$

$$J = \begin{bmatrix} \frac{\partial x}{\partial q_1} & \frac{\partial x}{\partial q_2} & \frac{\partial x}{\partial q_3} \\ \frac{\partial y}{\partial q_1} & \frac{\partial y}{\partial q_2} & \frac{\partial y}{\partial q_3} \\ \frac{\partial z}{\partial q_1} & \frac{\partial z}{\partial q_2} & \frac{\partial z}{\partial q_3} \end{bmatrix} = \begin{bmatrix} -Sq1(L_1 + {q_2}/{2}) & {Cq_1}/{2} & 0 \\ Cq1(L_1 + {q_2}/{2}) & {Sq_1}/{2} & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

$$v_2 = \begin{bmatrix} -Sq1(L_1 + {q_2}/{2}) & {Cq_1}/{2} & 0 \\ Cq1(L_1 + {q_2}/{2}) & {Sq_1}/{2} & 0 \\ 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} \dot{q}1 \\ \dot{q}2 \\ 0 \end{bmatrix} = \begin{bmatrix} -\dot{q}1[Sq1(L_1 + {q_2}/{2})] + \dot{q}2\,{Cq_1}/{2} \\ -\dot{q}1[Cq1(L_1 + {q_2}/{2})] + \dot{q}2\,{Sq_1}/{2} \\ 0 \end{bmatrix}$$

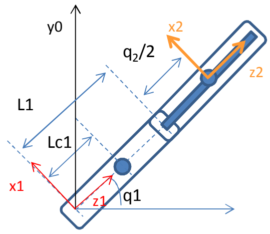
1 pausua: energia zinetikoaren kalkulua (K)

Kate-maila 2: $$K_2 = \frac{1}{2} m_2 v_2^T v_2 + \frac{1}{2} \omega_2^T I_2 \omega_2$$

Lehenengo kate-mailaren TMH a kalkulatzen dugu:

$$v_2^T v_2 = \begin{bmatrix} \dot{q}1[Sq1(L_1 + {}^{q_2}/_2)] + \dot{q}2\, {}^{Cq_1}/_2 & -\dot{q}1[Cq1(L_1 + {}^{q_2}/_2)] + \dot{q}2\, {}^{Sq_1}/_2 & 0 \end{bmatrix} \begin{bmatrix} -\dot{q}1[Sq1(L_1 + {}^{q_2}/_2)] + \dot{q}2\, {}^{Cq_1}/_2 \\ -\dot{q}1[Cq1(L_1 + {}^{q_2}/_2)] + \dot{q}2\, {}^{Sq_1}/_2 \\ 0 \end{bmatrix}$$

$$v_2^T v_2 = \dot{q}1^2 (L_1 + {}^{q_2}/_2)^2 + \dot{q}2^2 - 2\dot{q}1\dot{q}2(L_1 + {}^{q_2}/_2) S({}^{q_1}/_2)$$



2 kate-mailaren abiadura **angeluarra** : $\vec{w}_2 = \dot{q}_1 \vec{z}_0$

Terminoak batuz, 2 kate-mailaren energia zinetikoa:

$$K_2 = \frac{1}{2} m_2 \left[\dot{q}1^2 (L_1 + {}^{q_2}/_2)^2 + \dot{q}2^2 - 2\dot{q}1\dot{q}2(L_1 + {}^{q_2}/_2) S({}^{q_1}/_2) \right] + \frac{1}{2} I_2 \dot{q}_1^2$$

2. pausua: energia potentzialaren kalkulua (U)

Besoaren energia potentziala, robotaren kate-maila bakoitzen energia potentzialen batuketa da, hau da:

$$U = U(q)$$

$$U = \sum_{1=1}^{n} U_i \qquad U_i = m_i g^T p_{ci}$$

- **m$_i$**= i kate-mailaren masa
- **g**= grabitate-bektorea
- **p$_{ci}$**=i kate-mailaren masa-zentrua kokatzen duen bektorea, hasierako erreferentzi sistemarekiko

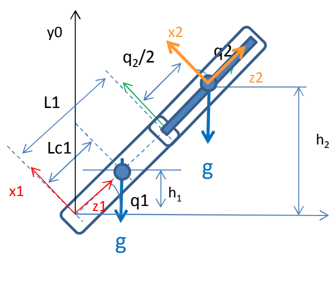
Matrize eran

1 kate-maila: h1

$$U_1 = m_1 g \underbrace{L_{c1} sen\, q_1}_{h1}$$

2 kate maila: h2

$$U_2 = m_2 g \underbrace{(L_1 + {}^{q_2}/_2) sen\, q_1}_{h2}$$



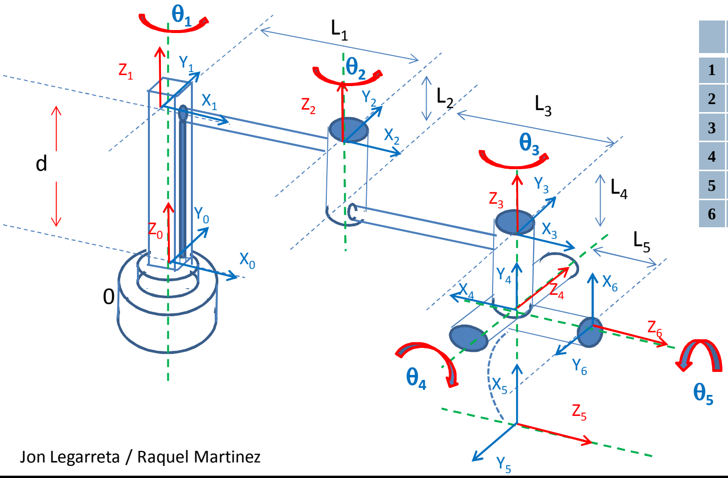
3. Pasua **Lagrangetarraren** kalkulua

$$L = \frac{1}{2} m_1 L_{c1}^2 \dot{q}_1^2 + \frac{1}{2} I_1 \dot{q}_1^2 + \frac{1}{2} m_2 \left[\dot{q}1^2 (L_1 + {}^{q_2}/_2)^2 + \dot{q}2^2 - 2\dot{q}1\dot{q}2(L_1 + {}^{q_2}/_2) S({}^{q_1}/_2) \right] + \frac{1}{2} I_2 \dot{q}_1^2 - m_1 g L_{c1} sen\, q_1 - m_2 g (L_1 + {}^{q_2}/_2) sen\, q_1$$

2 ARIKETA

6 askatasun graduko robotaren erreferentzi sistema izanik:(3.5 **puntu**)

1) D-Hen algoritmoa erabiliz, robotaren 6 artikulazioen erreferentzi sistemak esleitu (lehenengo artikulazioa prismatikoa eta besteak errotazionalak).
2) D-H algoritmoen parametroen taula lortu.



	θi	di	ai	αi
1	0	d	0	0
2	θ_1	0	L_1	0
3	θ_2	$-L_2$	L_3	0
4	θ_3+180	$-L_4$	0	90
5	θ_4+90	0	0	-90
6	θ_5	L_5	0	0

Jon Legarreta / Raquel Martinez