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Title: Reingeniería del Controlador de un Brazo Robótico de 6 g.d.l.

Author: Carla, CAMPOS-CALDERA, Javier E., ALDERETE-ALDERETE, Julio César, CORRUJEDO-LAZCANO, Juan Carlos, SOTO-ARMENTA

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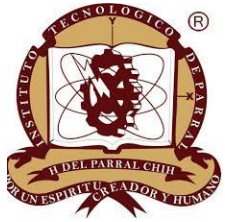
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ECORFAN-México, S.C.
244 – 2 Itzopan Street
La Florida, Ecatepec Municipality
Mexico State, 55120 Zipcode
Phone: +52 1 55 6159 2296
Skype: ecorfan-mexico.s.c.
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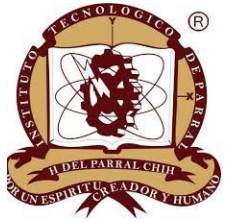
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Mexico	Colombia	Guatemala
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Spain	El Salvador	of Congo
Ecuador	Taiwan	Nicaragua
Peru	Paraguay	



Reingeniería del Controlador de un Brazo Robótico de 6 g.d.l.

1. Conceptos Básicos.
2. Metodología.
 - Modelo Cinemático.
 - Modelo dinámico.
3. Controlador.
4. Mundo Virtual.
5. Acondicionamiento.
6. Conclusiones y trabajos futuros.

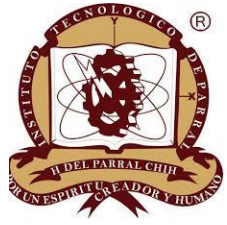


Reingeniería del Controlador de un Brazo Robótico de 6 g.d.l.

1. Conceptos Básicos.

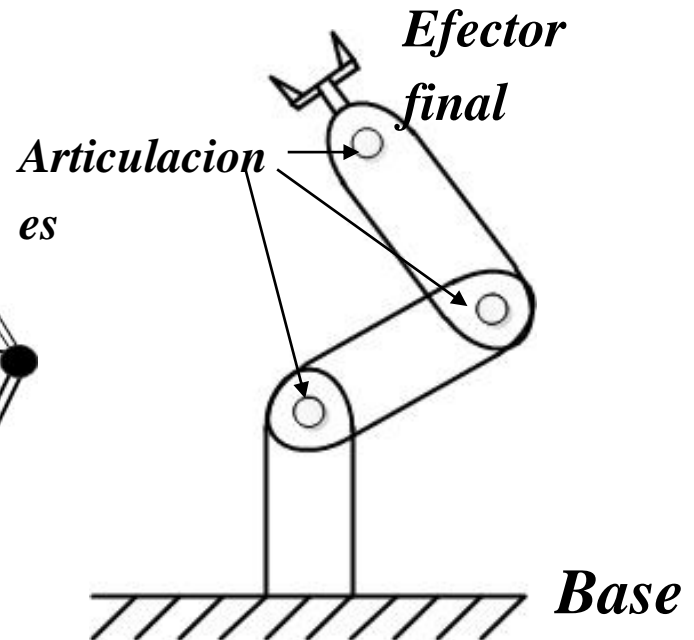
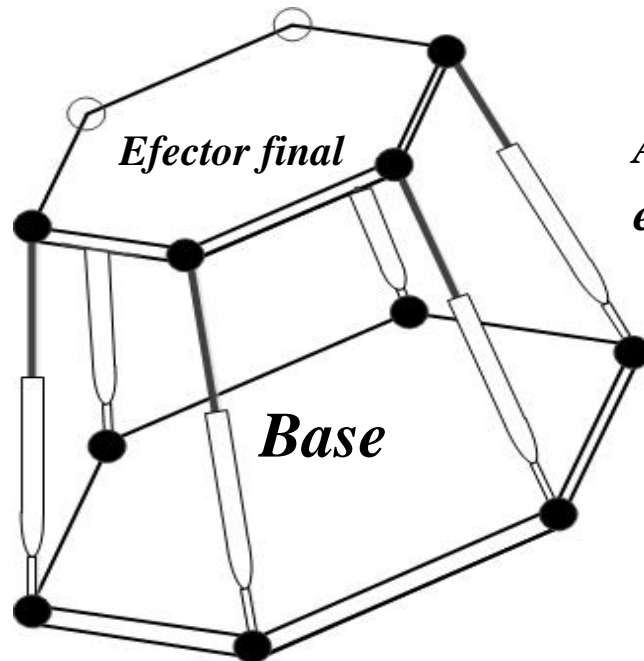
Federación Internacional de Robótica, bajo Norma ISO/TR 8373 (Kelly, Santibáñez y Loria , 2005.)

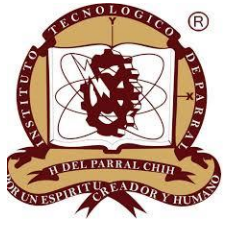




Reingeniería del Controlador de un Brazo Robótico de 6 g.d.l.

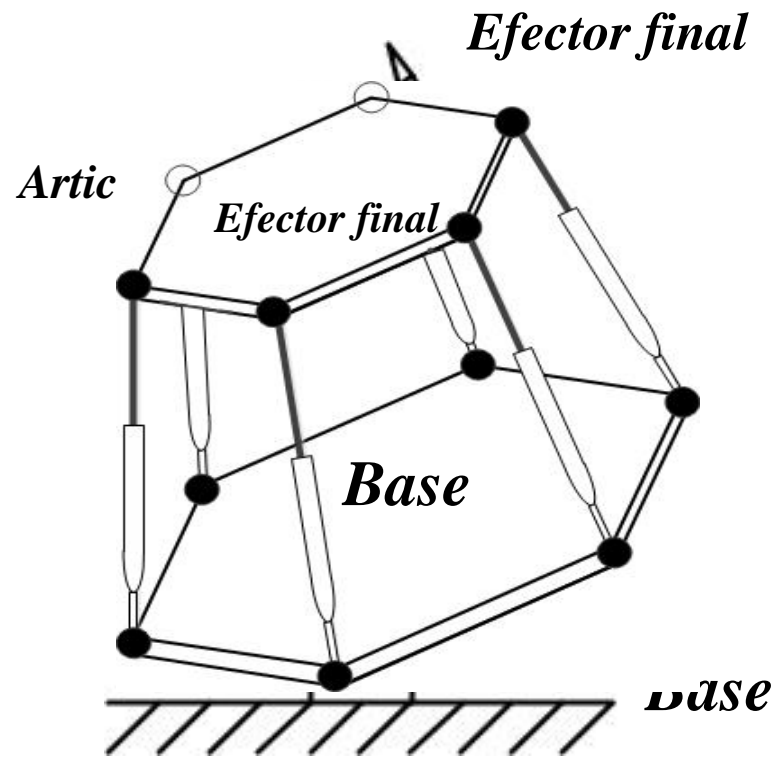
1. Conceptos Básicos.

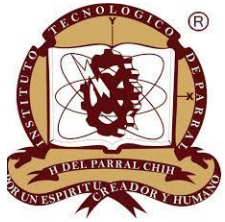




Reingeniería del Controlador de un Brazo Robótico de 6 g.d.l.

1. Conceptos Básicos.





Reingeniería del Controlador de un Brazo Robótico de 6 g.d.l.

2.1 Modelo Cinemático

$${}^0T_1 = \begin{bmatrix} \cos\theta_1 & 0 & \sin\theta_1 & 0 \\ \sin\theta_1 & 0 & -\cos\theta_1 & 0 \\ 0 & 1 & 0 & d_1 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$${}^1T_2 = \begin{bmatrix} \cos\theta_2 & -\sin\theta_2 & 0 & a_2 \cos\theta_2 \\ \sin\theta_2 & \cos\theta_2 & 0 & a_2 \sin\theta_2 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

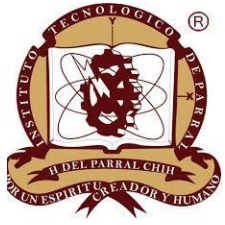
$${}^2T_3 = \begin{bmatrix} \cos\theta_3 & 0 & \sin\theta_3 & 0 \\ \sin\theta_3 & 0 & -\cos\theta_3 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$${}^3T_4 = \begin{bmatrix} \cos\theta_4 & 0 & -\sin\theta_4 & 0 \\ \sin\theta_4 & 0 & \cos\theta_4 & 0 \\ 0 & -1 & 0 & d_4 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$${}^4T_5 = \begin{bmatrix} \cos\theta_5 & 0 & \sin\theta_5 & 0 \\ \sin\theta_5 & 0 & -\cos\theta_5 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

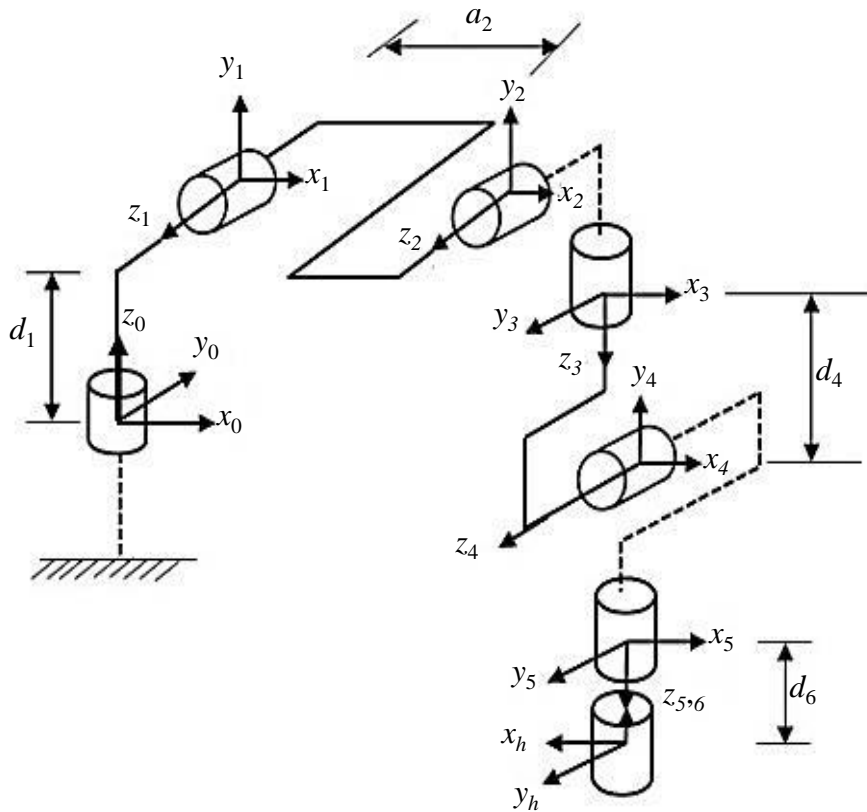
$${}^5T_6 = \begin{bmatrix} \cos\theta_6 & -\sin\theta_6 & 0 & 0 \\ \sin\theta_6 & \cos\theta_6 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$${}^6T_h = \begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & -1 & 0 & 0 \\ 1 & 0 & 0 & d_6 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

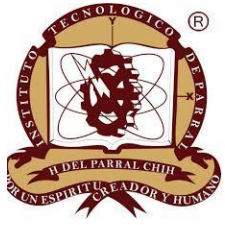


Reingeniería del Controlador de un Brazo Robótico de 6 g.d.l.

2.1 Modelo Cinemático.

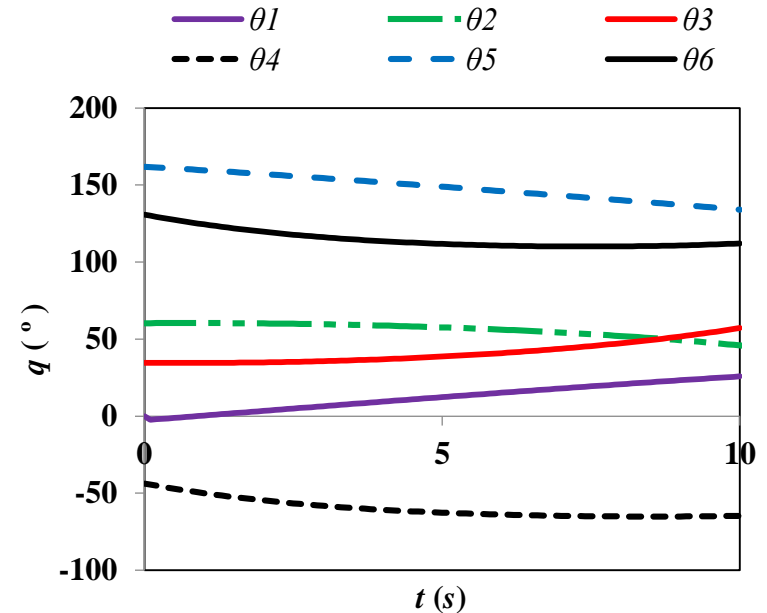
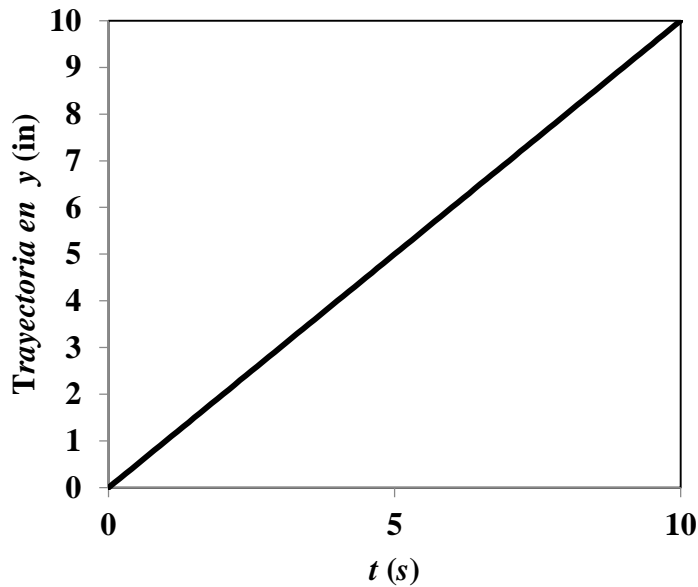


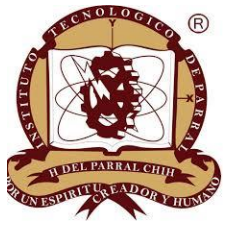
i	a_i	α_i	d_i	θ_i
1	a_2	$\pi/2$	d_1	θ_1
2	0	0	0	θ_2
3	0	$\pi/2$	0	θ_3
4	0	$-\pi/2$	d_4	θ_4
5	0	$\pi/2$	0	θ_5
6	0	0	d_6	θ_6



Reingeniería del Controlador de un Brazo Robótico de 6 g.d.l.

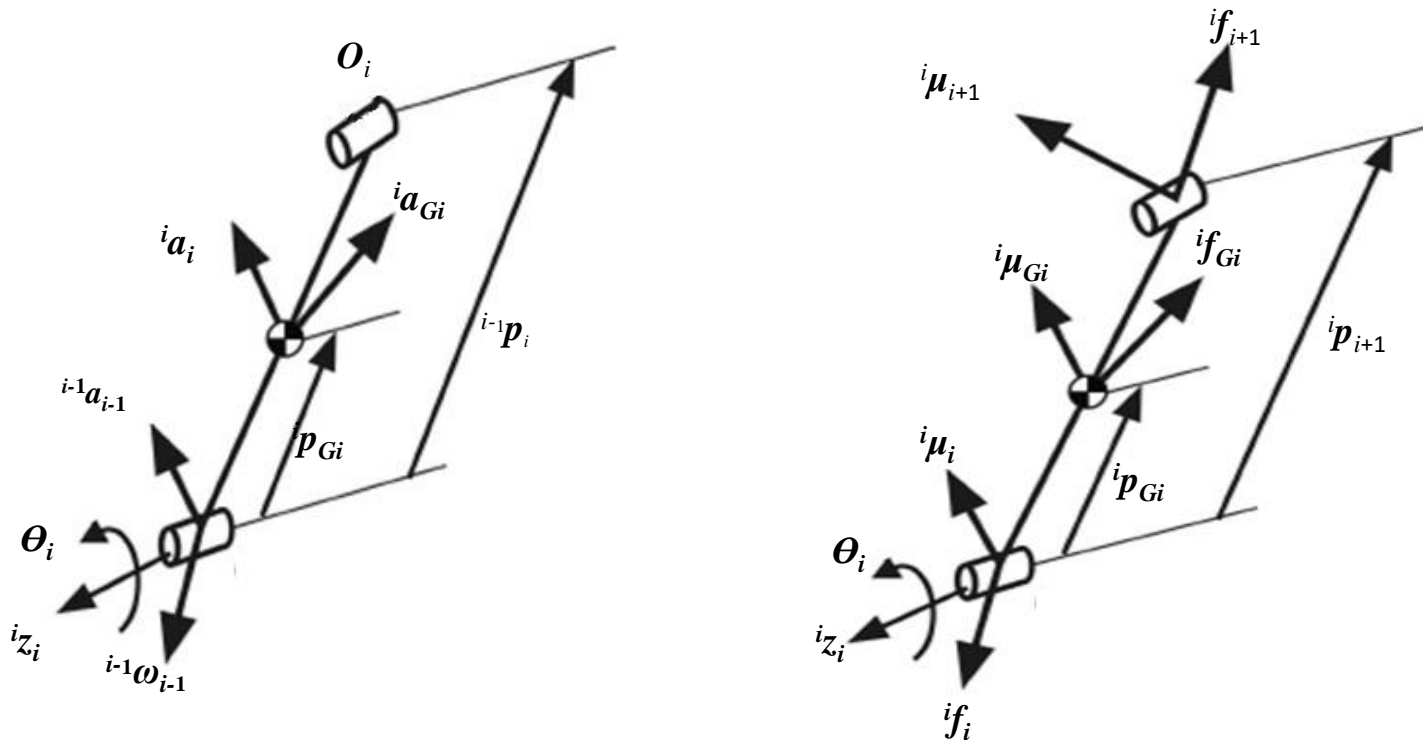
2.1 Modelo Cinemático.

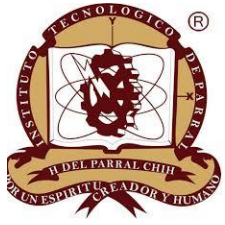




Reingeniería del Controlador de un Brazo Robótico de 6 g.d.l.

2.2 Modelo Dinámico.





Reingeniería del Controlador de un Brazo Robótico de 6 g.d.l.

- Modelo Dinámico.

$${}^i \mathbf{p}_i = {}^i R_{i-1} {}^{i-1} \mathbf{p}_i$$

$${}^i \boldsymbol{\omega}_{i-1} = {}^i R_{i-1} {}^{i-1} \boldsymbol{\omega}_{i-1}$$

$${}^i \dot{\boldsymbol{\omega}}_{i-1} = {}^i R_{i-1} {}^{i-1} \dot{\boldsymbol{\omega}}_{i-1}$$

$${}^i \mathbf{a}_{i-1} = {}^i R_{i-1} {}^{i-1} \mathbf{a}_{i-1}$$

$${}^i \boldsymbol{\omega}_i = {}^i \boldsymbol{\omega}_{i-1} + \dot{\theta}_i {}^i \mathbf{z}_i$$

$${}^i \dot{\boldsymbol{\omega}}_i = {}^i \dot{\boldsymbol{\omega}}_{i-1} + \ddot{\theta}_i {}^i \mathbf{z}_i + {}^i \boldsymbol{\omega}_i \times \dot{\theta}_i {}^i \mathbf{z}_i$$

$${}^i \mathbf{a}_i = {}^i \mathbf{a}_{i-1} + {}^i \dot{\boldsymbol{\omega}}_{i-1} \times {}^i \mathbf{p}_i + {}^i \boldsymbol{\omega}_{i-1} \times ({}^i \boldsymbol{\omega}_{i-1} \times {}^i \mathbf{p}_i)$$

$${}^i \mathbf{a}_{G_i} = {}^i \mathbf{a}_i + {}^i \dot{\boldsymbol{\omega}}_i \times {}^i \mathbf{p}_{G_i} + {}^i \boldsymbol{\omega}_i \times ({}^i \boldsymbol{\omega}_i \times {}^i \mathbf{p}_{G_i}) + {}^i \mathbf{g}_i$$

$${}^i \mathbf{f}_{G_i} = m_i {}^i \mathbf{a}_{G_i}$$

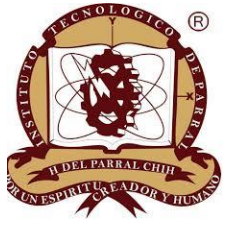
$${}^i \boldsymbol{\mu}_{G_i} = I_i {}^i \dot{\boldsymbol{\omega}}_i + {}^i \boldsymbol{\omega}_i \times (I_i {}^i \boldsymbol{\omega}_i)$$

$${}^i \mathbf{f}_i = {}^i \mathbf{f}_{i+1} + {}^i \mathbf{f}_{G_i}$$

$${}^i \boldsymbol{\mu}_i = {}^i \boldsymbol{\mu}_{G_i} + {}^i \boldsymbol{\mu}_{i+1} + ({}^i \mathbf{p}_{G_i} \times {}^i \mathbf{f}_{G_i}) + ({}^i \mathbf{p}_{i+1} \times {}^i \mathbf{f}_{i+1})$$

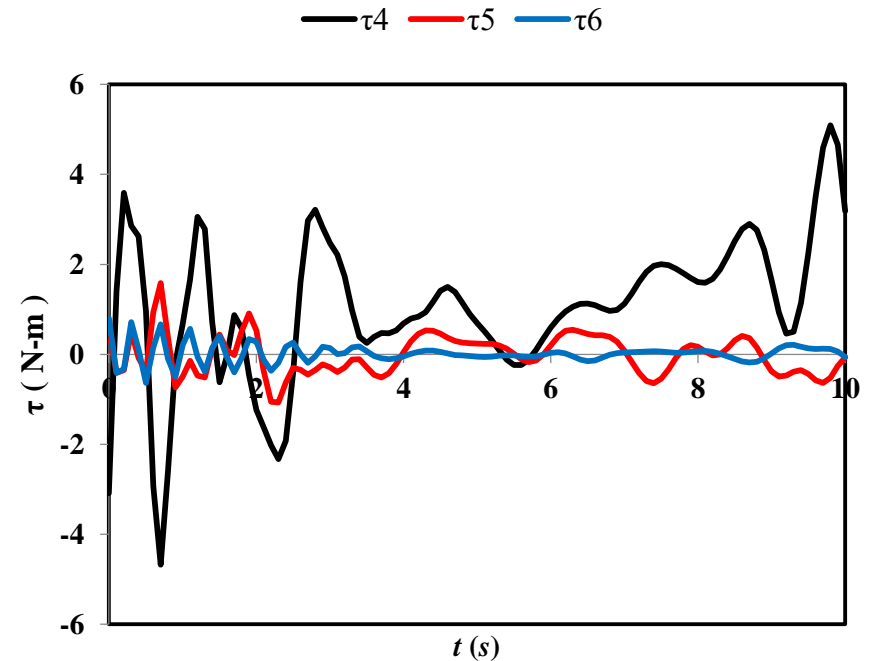
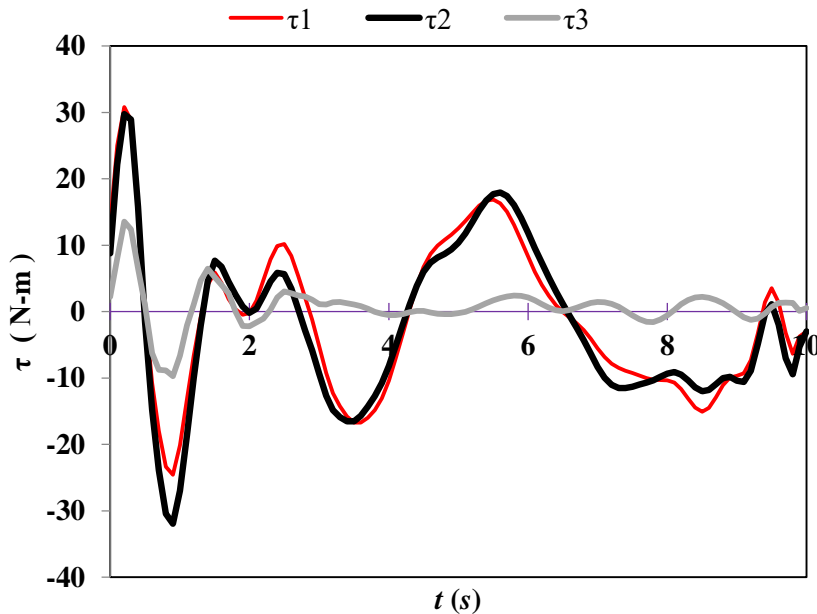
$${}^i \mathbf{f}_{i+1} = {}^{i+1} R_i^T {}^i \mathbf{f}_{i+1}$$

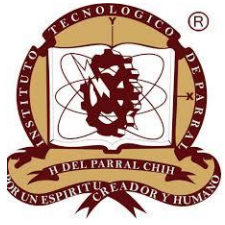
$${}^i \boldsymbol{\mu}_{i+1} = {}^{i+1} R_i^T {}^i \boldsymbol{\mu}_{i+1}$$



Reingeniería del Controlador de un Brazo Robótico de 6 g.d.l.

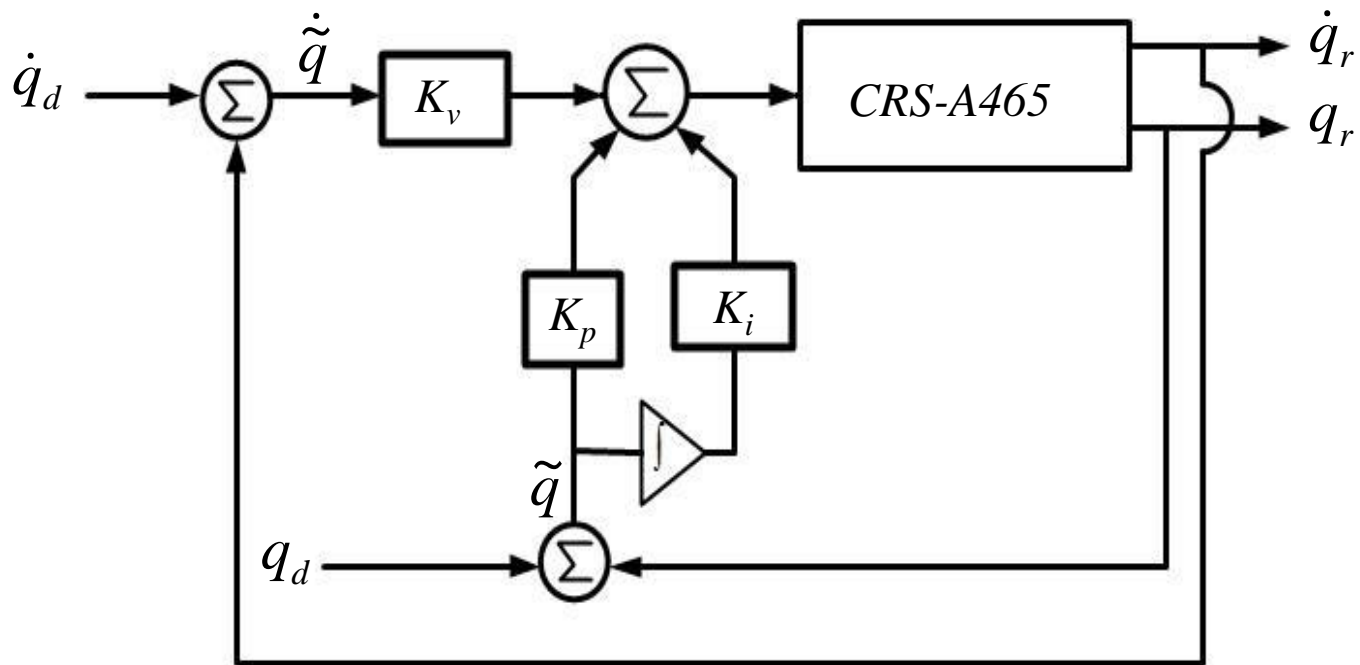
- Modelo Dinámico.



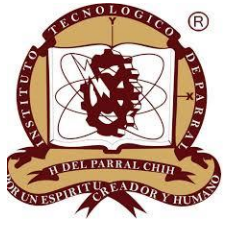


Reingeniería del Controlador de un Brazo Robótico de 6 g.d.l.

- Controlador.

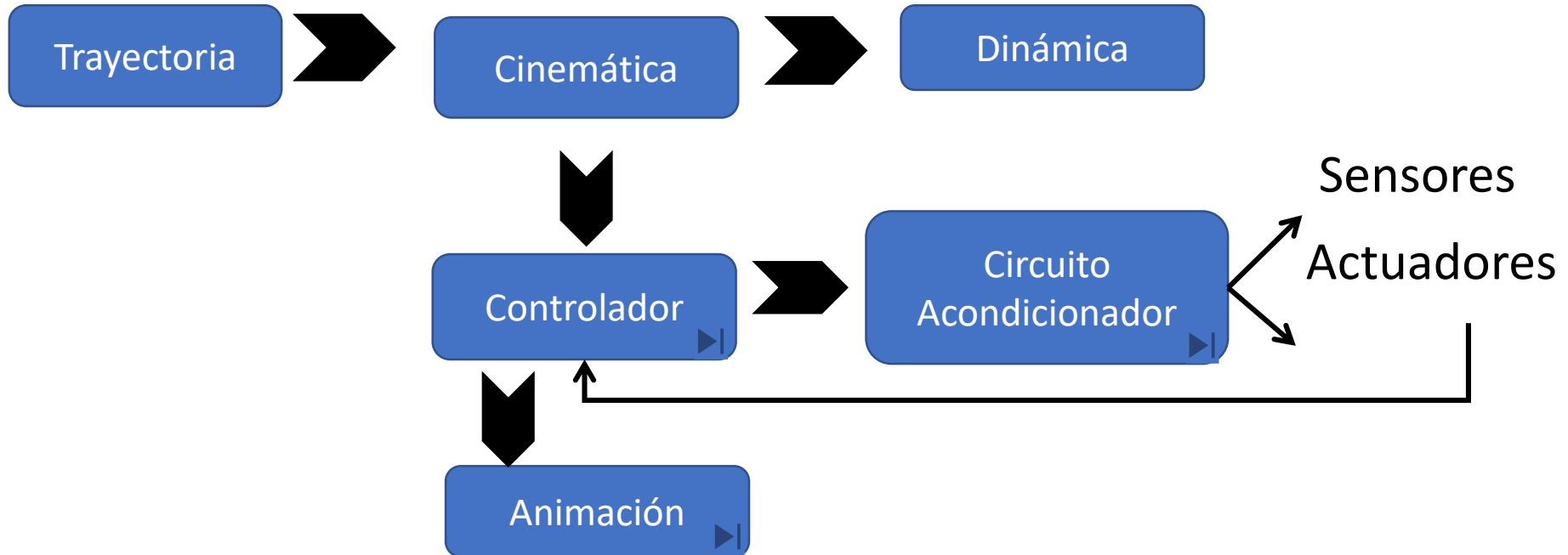


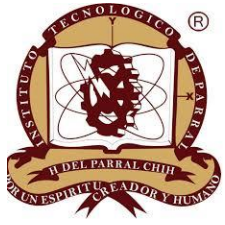
$$\tau = K_p \tilde{q} + K_v \dot{\tilde{q}} + K_i \int \tilde{q}$$



Reingeniería del Controlador de un Brazo Robótico de 6 g.d.l.

4. Mundo Virtual.





Reingeniería del Controlador de un Brazo Robótico de 6 g.d.l.

3. Controlador.

$${}^i \mathbf{f}_{Gi} = m_i {}^i \mathbf{a}_{Gi}$$

$${}^i \boldsymbol{\mu}_{Gi} = I_i {}^i \dot{\boldsymbol{\omega}}_i + {}^i \boldsymbol{\omega}_i \times (I_i {}^i \boldsymbol{\omega}_i)$$

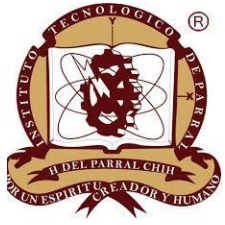
$${}^i \mathbf{f}_i = {}^i \mathbf{f}_{i+1} + {}^i \mathbf{f}_{Gi}$$

$${}^i \boldsymbol{\mu}_i = {}^i \boldsymbol{\mu}_{Gi} + {}^i \boldsymbol{\mu}_{i+1} + ({}^i \mathbf{p}_{Gi} \times {}^i \mathbf{f}_{Gi}) + ({}^i \mathbf{p}_{i+1} \times {}^i \mathbf{f}_{i+1})$$

$${}^i \mathbf{f}_{i+1} = {}^{i+1} R_i^T {}^i \mathbf{f}_{i+1}$$

$${}^i \boldsymbol{\mu}_{i+1} = {}^{i+1} R_i^T {}^i \boldsymbol{\mu}_{i+1}$$

$$M(\mathbf{q})\ddot{\mathbf{q}} + C(\mathbf{q}, \dot{\mathbf{q}})\dot{\mathbf{q}} + g(\mathbf{q}) = \boldsymbol{\tau}$$



Reingeniería del Controlador de un Brazo Robótico de 6 g.d.l.

3. Controlador.

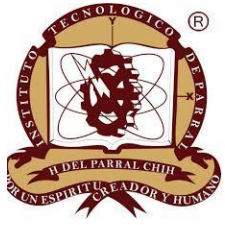
$$\lambda_{MAX} \{K_i\} \geq \lambda_{min} \{K_i\} > 0$$

$$\lambda_{MAX} \{Kp\} \geq \lambda_{min} \{Kp\} > K_g$$

$$\lambda_{MAX} \{Kv\} \geq \lambda_{min} \{Kv\} > \frac{\lambda_{MAX} \{K_i\}}{\lambda_{min} \{K_p\} - K_g} \cdot \frac{\lambda_{MAX}^2 \{M\}}{\lambda_{min} \{M\}}$$

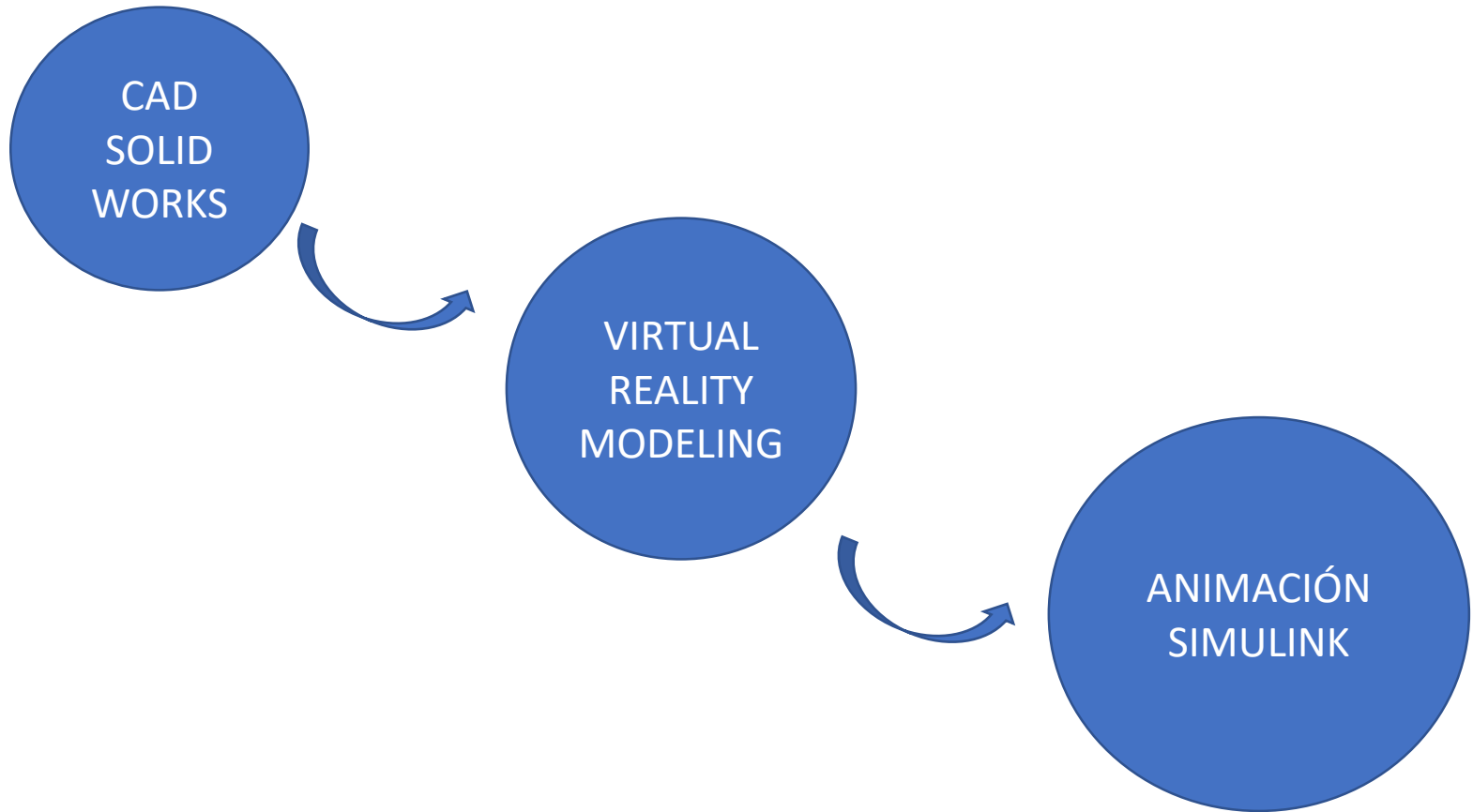
$$K_g = n \left[\text{Max}_{i,j,q} \left| \frac{\partial g_i(\mathbf{q})}{\partial q_j} \right| \right]$$

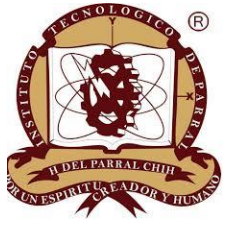




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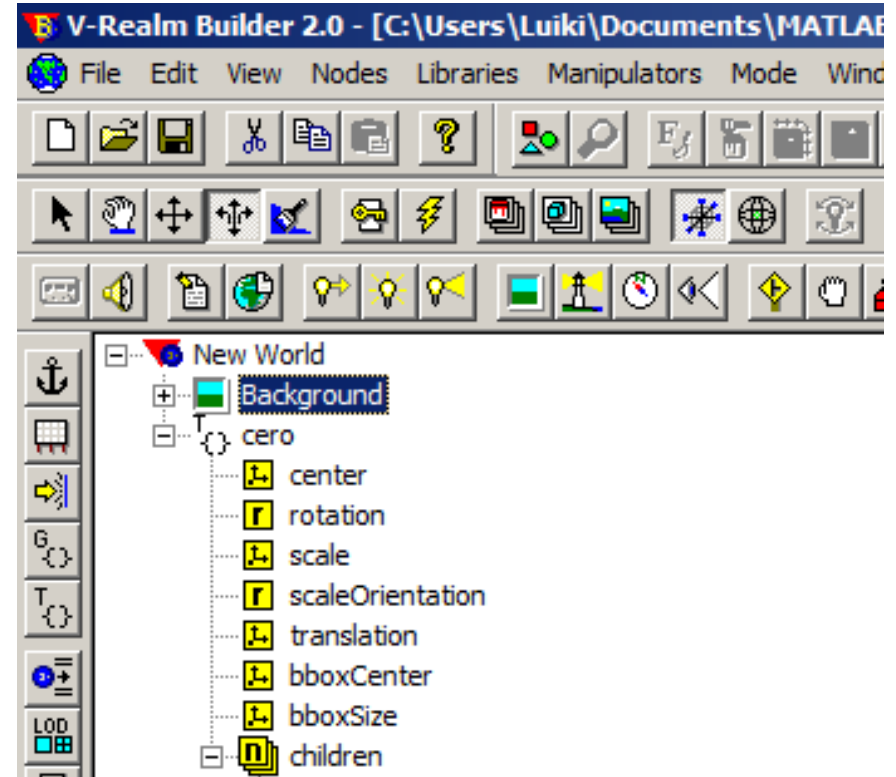
4. Mundo Virtual.

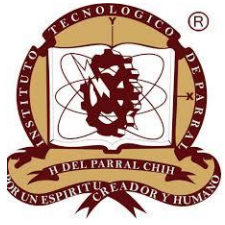




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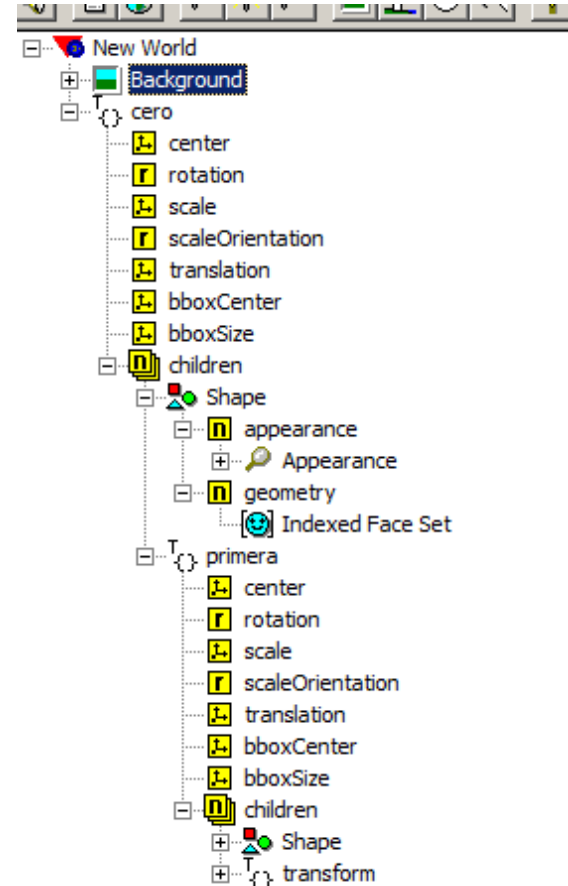
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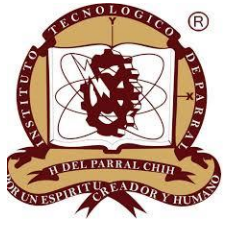




Reingeniería del Controlador de un Brazo Robótico de 6 g.d.l.

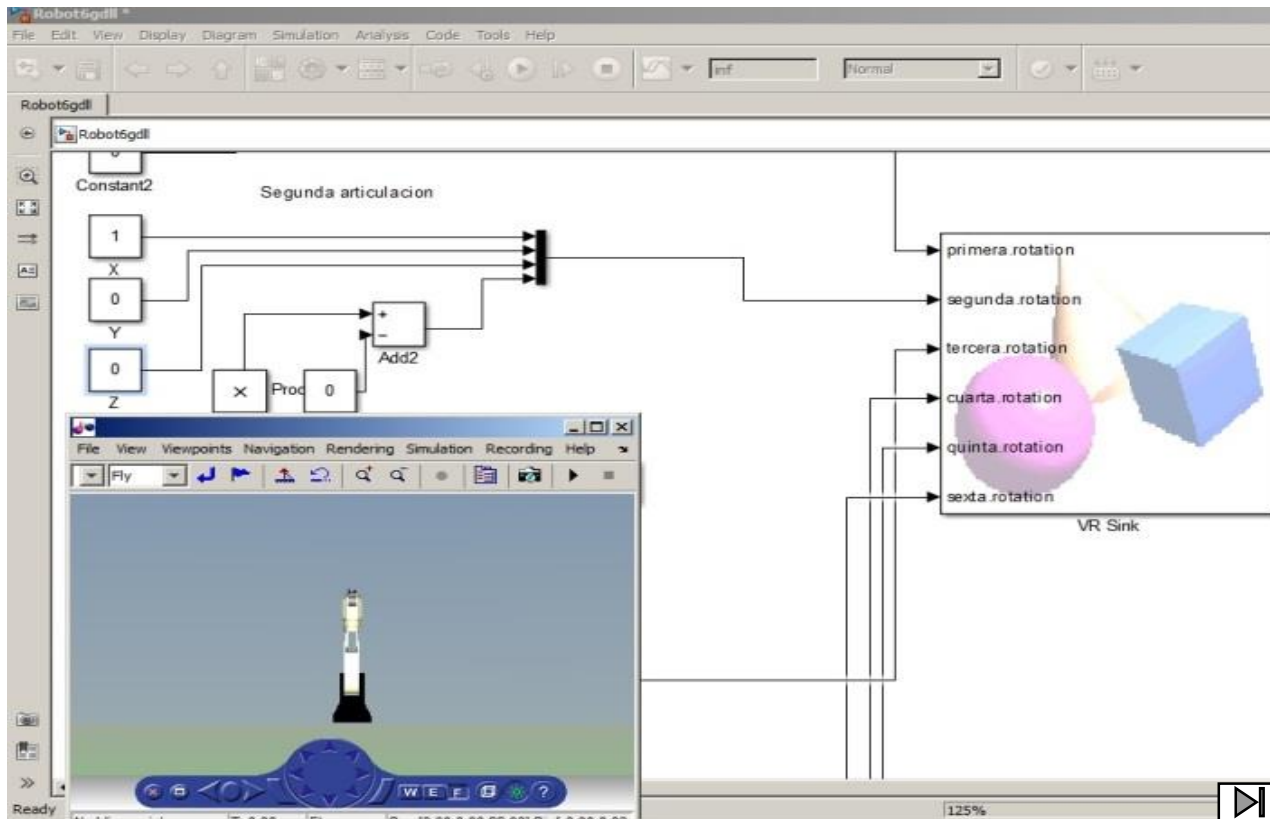
4. Mundo Virtual.

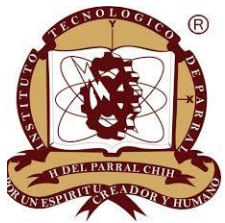




Reingeniería del Controlador de un Brazo Robótico de 6 g.d.l.

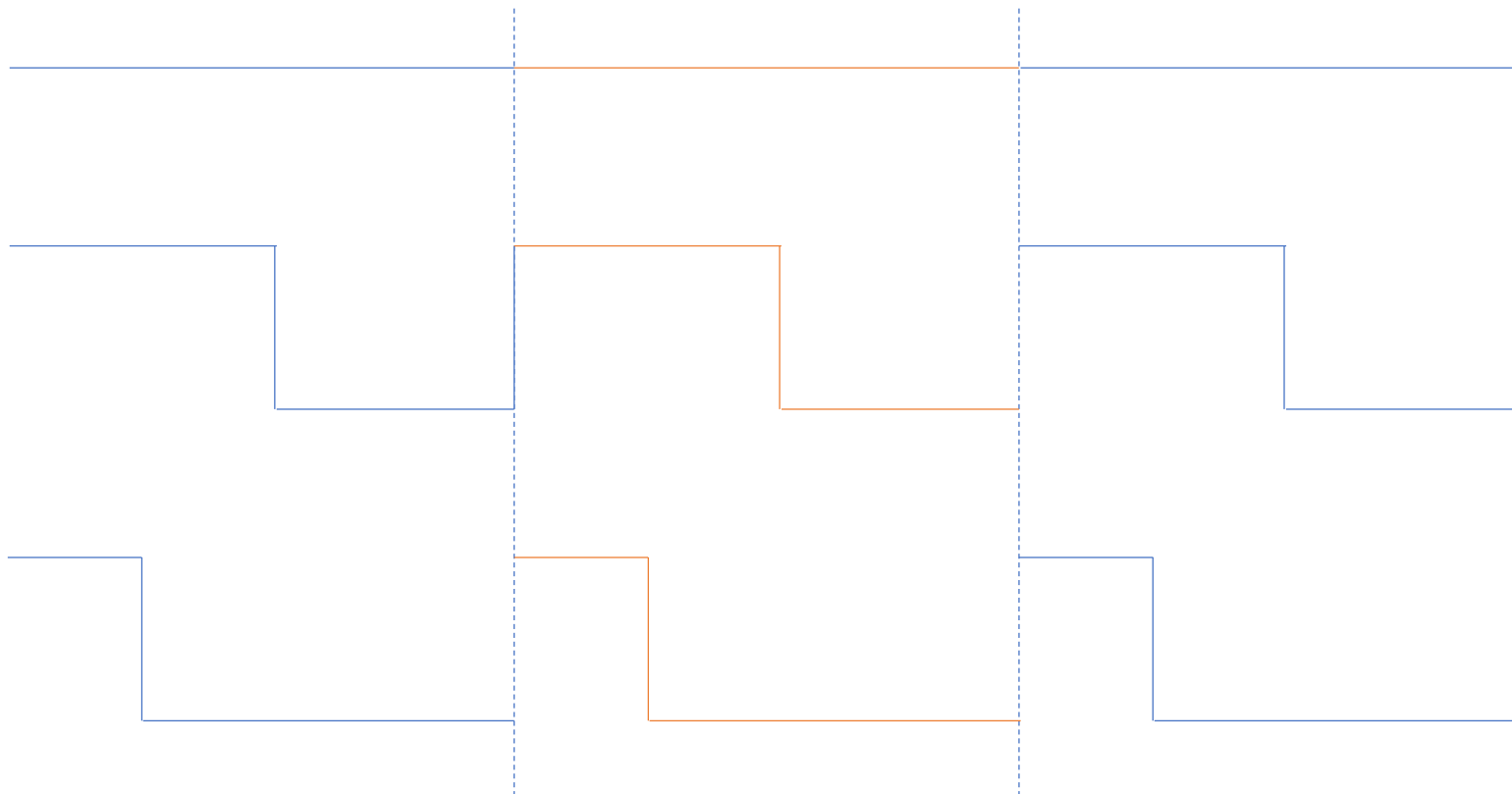
4. Mundo Virtual.



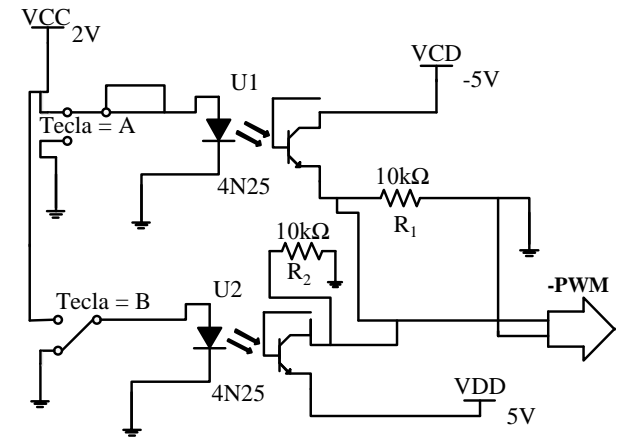
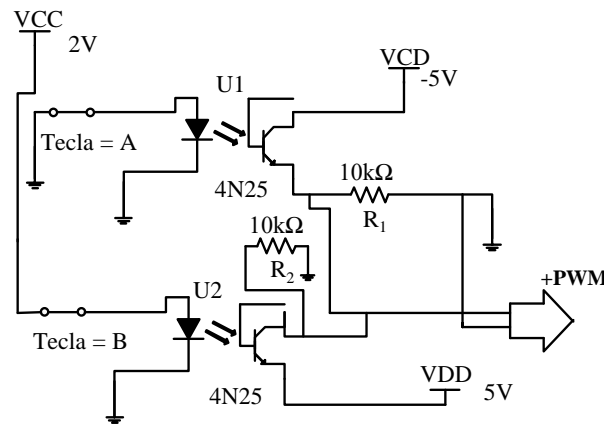


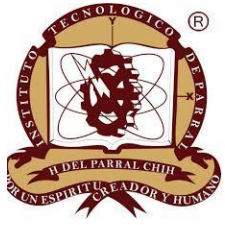
Reingeniería del Controlador de un Brazo Robótico de 6 g.d.l.

- PWM



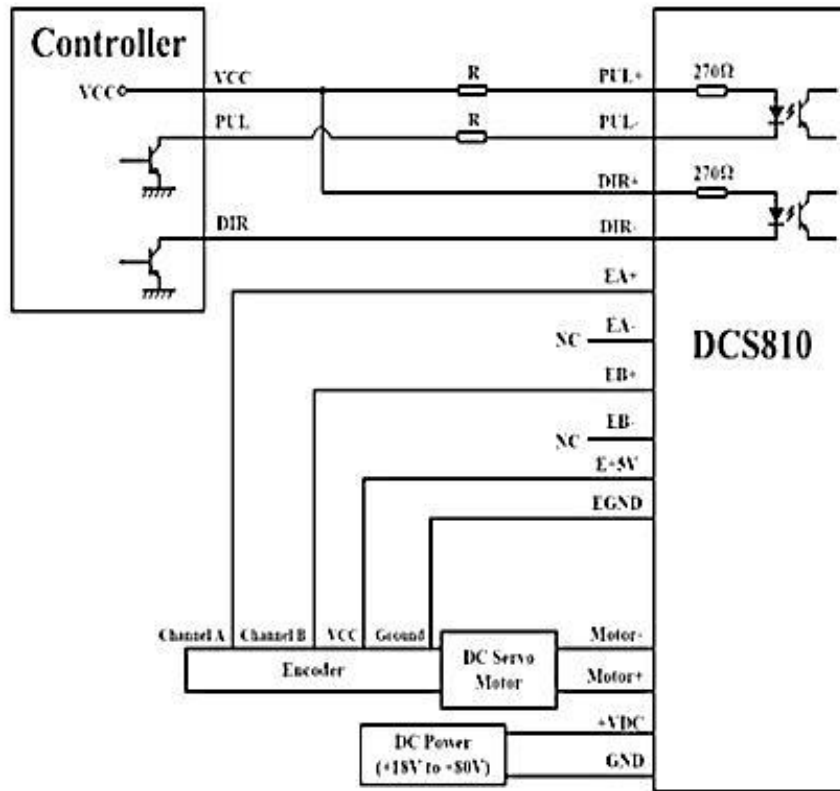
5. Acondicionamiento.



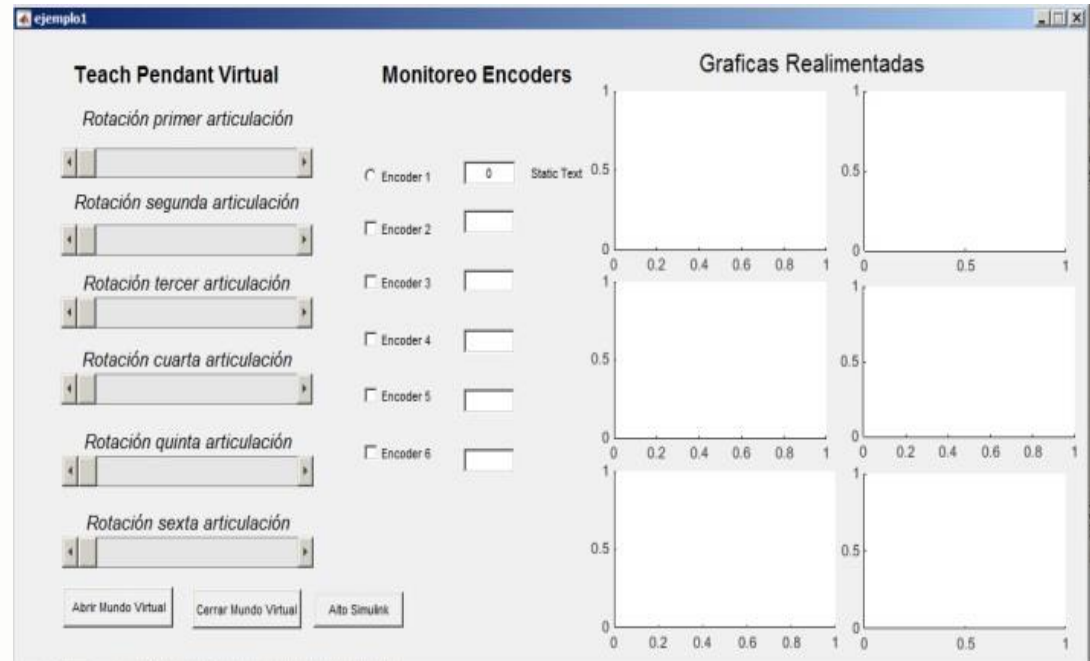


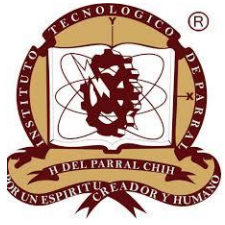
Reingeniería del Controlador de un Brazo Robótico de 6 g.d.l.

5. Acondicionamiento.



6. GUI.





Reingeniería del Controlador de un Brazo Robótico de 6 g.d.l.

7. Conclusiones y trabajos futuros.

- El esquema de control que se implementa es un clásico controlador PID, destacándose que los circuitos acondicionadores así como la selección de la tarjeta adquisitora, el DCS810 y la interfaz gráfica es una contribución original al esquema de control que de fábrica.
- Las opciones de visualización de nuestra GUI aún se siguen mejorando, se pretende agregar una opción que permita trabajar con otros esquemas de control.



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