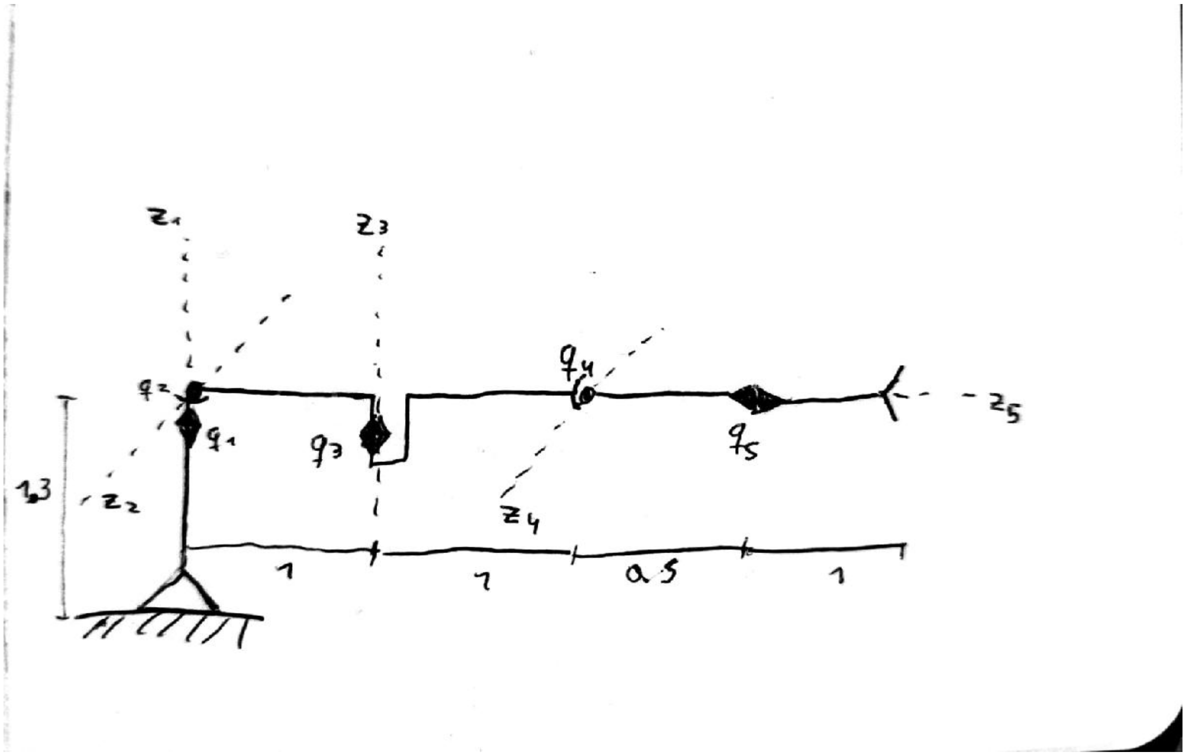
Entregable 2

Esquema del robot



Construir tabla de Denavit-Hatemberg

```
syms q1 q2 q3 q4 q5 l1 l2 l3 l4 l5

%La funcion DH la he creado obtener A a partir de cada entrada de la tabla
%de Denavit-Hatemberg
A0_1 = simplify(DH((q1*180/pi),   l1,0,     90))
```

A0_1 =

$$\begin{pmatrix} \cos(q_1) & 0 & \sin(q_1) & 0 \\ \sin(q_1) & 0 & -\cos(q_1) & 0 \\ 0 & 1 & 0 & l_1 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

```
A1_2 = simplify(DH((q2*180/pi),   0, l2,   -90))
```

A1_2 =

$$\begin{pmatrix} \cos(q_2) & 0 & -\sin(q_2) & l_2\cos(q_2) \\ \sin(q_2) & 0 & \cos(q_2) & l_2\sin(q_2) \\ 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

```
A2_3 = simplify(DH((q3*180/pi),   0, l3,   90 ))
```

A2_3 =

$$\begin{pmatrix} \cos(q_3) & 0 & \sin(q_3) & l_3\cos(q_3) \\ \sin(q_3) & 0 & -\cos(q_3) & l_3\sin(q_3) \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

```
A3_4 = simplify(DH((q4*180/pi),   0, l4+l5,0  ))
```

A3_4 =

$$\begin{pmatrix} \cos(q_4) & -\sin(q_4) & 0 & \cos(q_4)\,(l_4+l_5) \\ \sin(q_4) & \cos(q_4) & 0 & \sin(q_4)\,(l_4+l_5) \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

```
A4_5 = simplify(DH(90+(q5*180/pi),0, 0,    90 ))
```

A4_5 =

$$\begin{pmatrix} -\sin(q_5) & 0 & \cos(q_5) & 0 \\ \cos(q_5) & 0 & \sin(q_5) & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

Cinemática directa

```
T = A0_1 * A1_2 * A2_3 * A3_4 * A4_5;
T = simplify(T)
```

T =

$$\begin{pmatrix} \cos(q_5)\,\sigma_5+\sin(q_5)\,\sigma_6 & \cos(q_3)\sin(q_1)+\cos(q_1)\cos(q_2)\sin(q_3) & \sin(q_5)\,\sigma_5-\cos(q_5)\,\sigma_6 & l_2\cos(q_1)\cos(\\ -\cos(q_5)\,\sigma_4-\sin(q_5)\,\sigma_3 & \cos(q_2)\sin(q_1)\sin(q_3)-\cos(q_1)\cos(q_3) & \cos(q_5)\,\sigma_3-\sin(q_5)\,\sigma_4 & l_2\cos(q_2)\sin(\\ \cos(q_5)\,\sigma_1-\sin(q_5)\,\sigma_2 & \sin(q_2)\sin(q_3) & \cos(q_5)\,\sigma_2+\sin(q_5)\,\sigma_1 & l_1 \\ 0 & 0 & 0 & \end{pmatrix}$$

where

$$\sigma_1=\cos(q_2)\cos(q_4)-\cos(q_3)\sin(q_2)\sin(q_4)$$

$$\sigma_2=\cos(q_2)\sin(q_4)+\cos(q_3)\cos(q_4)\sin(q_2)$$

$$\sigma_3=\cos(q_4)\,\sigma_7-\sin(q_1)\sin(q_2)\sin(q_4)$$

$$\sigma_4=\sin(q_4)\,\sigma_7+\cos(q_4)\sin(q_1)\sin(q_2)$$

$$\sigma_5=\sin(q_4)\,\sigma_8-\cos(q_1)\cos(q_4)\sin(q_2)$$

$$\sigma_6=\cos(q_4)\,\sigma_8+\cos(q_1)\sin(q_2)\sin(q_4)$$

$$\sigma_7=\cos(q_1)\sin(q_3)+\cos(q_2)\cos(q_3)\sin(q_1)$$

$$\sigma_8=\sin(q_1)\sin(q_3)-\cos(q_1)\cos(q_2)\cos(q_3)$$

```
Px = simplify(T(1,4))
```

Px = $l_2\cos(q_1)\cos(q_2)-l_3\sin(q_1)\sin(q_3)-\cos(q_4)\,(l_4+l_5)\,(\sin(q_1)\sin(q_3)-\cos(q_1)\cos(q_2)\cos(q_3))-\cos(q_1)$

```
Py = T(2,4)
```

Py = $l_2\cos(q_2)\sin(q_1)+l_3\cos(q_1)\sin(q_3)+\cos(q_4)\,(l_4+l_5)\,(\cos(q_1)\sin(q_3)+\cos(q_2)\cos(q_3)\sin(q_1))-\sin(q_1)$

```
Pz = T(3,4)
```

Pz = $l_1+l_2\sin(q_2)+\cos(q_2)\sin(q_4)\,(l_4+l_5)+l_3\cos(q_3)\sin(q_2)+\cos(q_3)\cos(q_4)\sin(q_2)\,(l_4+l_5)$

Cinemática Inversa

Suponiendo q2=0 y q5=0

```
Px = simplify(subs(Px, [q2,q5],[0,0]))
```

Px = $l_3\cos(q_1+q_3)+l_2\cos(q_1)+\cos(q_1+q_3)\cos(q_4)\,(l_4+l_5)$

```
Py = simplify(subs(Py, [q2,q5],[0,0]))
```

Py = $l_3 \sin(q_1 + q_3) + l_2 \sin(q_1) + \sin(q_1 + q_3) \cos(q_4)\ (l_4 + l_5)$

```
Pz = simplify(subs(Pz, [q2,q5],[0,0]))
```

Pz = $l_1 + \sin(q_4)\ (l_4 + l_5)$

```
syms X Y Z

ik = solve([Px==X,Py==Y], [q1,q3],'Real', true);
```

Warning: Solutions are only valid under certain conditions. To include parameters and conditions in the solution, specify the 'ReturnConditions' value as 'true'.

```
solq1 = simplify(ik.q1,'Steps',30)
```

solq1 =

$$\begin{pmatrix} 2\,\mathrm{atan}\left(\dfrac{\left(\sigma_1 - \dfrac{8\,Y\,l_2^2\,\sigma_4}{\sigma_3\,\sigma_2}\right)\sigma_2}{4\,l_2\,\sigma_4}\right) \\ -2\,\mathrm{atan}\left(\dfrac{\left(\sigma_1 + \dfrac{8\,Y\,l_2^2\,\sigma_4}{\sigma_3\,\sigma_2}\right)\sigma_2}{4\,l_2\,\sigma_4}\right) \end{pmatrix}$$

where

$$\sigma_1 = \frac{4\,l_2\,\sigma_4\,\sqrt{-\dfrac{\sigma_2\,\left(-X^2 - Y^2 + l_2^2 + 2\,l_2\,l_3 + 2\,l_2\,l_4\cos(q_4) + 2\,l_2\,l_5\cos(q_4) + l_3^2 + 2\,l_3\,l_4\cos(q_4) + 2\,l_3\,l_5}{\sigma_3^4}}}{\sigma_2}$$

$$\sigma_2 = -X^2 - Y^2 + l_2^2 - 2\,l_2\,l_3 - 2\,l_2\,l_4\cos(q_4) - 2\,l_2\,l_5\cos(q_4) + l_3^2 + 2\,l_3\,l_4\cos(q_4) + 2\,l_3\,l_5\cos(q_4) + \sigma_7 +$$

$$\sigma_3 = -X^2 - 2\,X\,l_2 - Y^2 - l_2^2 + l_3^2 + 2\,l_3\,l_4\cos(q_4) + 2\,l_3\,l_5\cos(q_4) + \sigma_7 + \sigma_5 + \sigma_6$$

$$\sigma_4 = l_3 + l_4\cos(q_4) + l_5\cos(q_4)$$

$$\sigma_5 = 2\,l_4\,l_5\cos(q_4)^2$$

$$\sigma_6 = l_5^2\cos(q_4)^2$$

$$\sigma_7 = l_4^2\cos(q_4)^2$$

```
solq3 = simplify(ik.q3,'Steps',30)
```

solq3 =

$$\begin{pmatrix} -\sigma_1 \\ \sigma_1 \end{pmatrix}$$

where

$$\sigma_1 = 2\,\mathrm{atan}\left(\frac{\sqrt{-\dfrac{\sigma_2\,\left(-X^2 - Y^2 + {l_2}^2 + 2\,l_2\,l_3 + 2\,l_2\,l_4\cos(q_4) + 2\,l_2\,l_5\cos(q_4) + {l_3}^2 + 2\,l_3\,l_4\cos(q_4) + 2\,l_3\,l_5}{{\sigma_3}^4}}}{\sigma_2}\right.$$

$$\sigma_2 = -X^2 - Y^2 + {l_2}^2 - 2\,l_2\,l_3 - 2\,l_2\,l_4\cos(q_4) - 2\,l_2\,l_5\cos(q_4) + {l_3}^2 + 2\,l_3\,l_4\cos(q_4) + 2\,l_3\,l_5\cos(q_4) + \sigma_6 +$$

$$\sigma_3 = -X^2 - 2\,X\,l_2 - Y^2 - {l_2}^2 + {l_3}^2 + 2\,l_3\,l_4\cos(q_4) + 2\,l_3\,l_5\cos(q_4) + \sigma_6 + \sigma_4 + \sigma_5$$

$$\sigma_4 = 2\,l_4\,l_5\cos(q_4)^2$$

$$\sigma_5 = {l_5}^2\cos(q_4)^2$$

$$\sigma_6 = {l_4}^2\cos(q_4)^2$$

```
solq4 = simplify(solve([Pz==Z], [q4])) % Es lo mismo
```

solq4 =

$$\begin{pmatrix} \mathrm{asin}\left(\dfrac{Z - l_1}{l_4 + l_5}\right) \\ \pi - \mathrm{asin}\left(\dfrac{Z - l_1}{l_4 + l_5}\right) \end{pmatrix}$$

Función para determinar la posicion

```
[q1,q2,q3,q4,q5] = Pos(-0.2,2.4,2.4) % Con los resultados del Aula Virtual
```

```
q1 = 1×2
    0.6833    2.6246
q2 = 0
q3 = 1×2
    1.3915   -1.3915
q4 = 0.8232
q5 = 0
```

```
[q1,q2,q3,q4,q5] = myPos(-0.2,2.4,2.4)  % Con mis resultados
```

```
q1 = 2×1
    0.6833
    2.6246
q2 = 0
q3 = 2×1
    1.3915
```

```
   -1.3915
q4 = 0.8232
q5 = 0
```

Aqui se puede ver que aunque den otra formula, en realidad son iguales.

```
% Mas ejemplos
% [q1,q2,q3,q4,q5] = Pos(2.8,-1,1.8)
% [q1,q2,q3,q4,q5] = Pos(1.4,-1.4,0)
% [q1,q2,q3,q4,q5] = Pos(3.25,0,1.3)
% [q1,q2,q3,q4,q5] = Pos(0.5,-2.25,0.1)
```