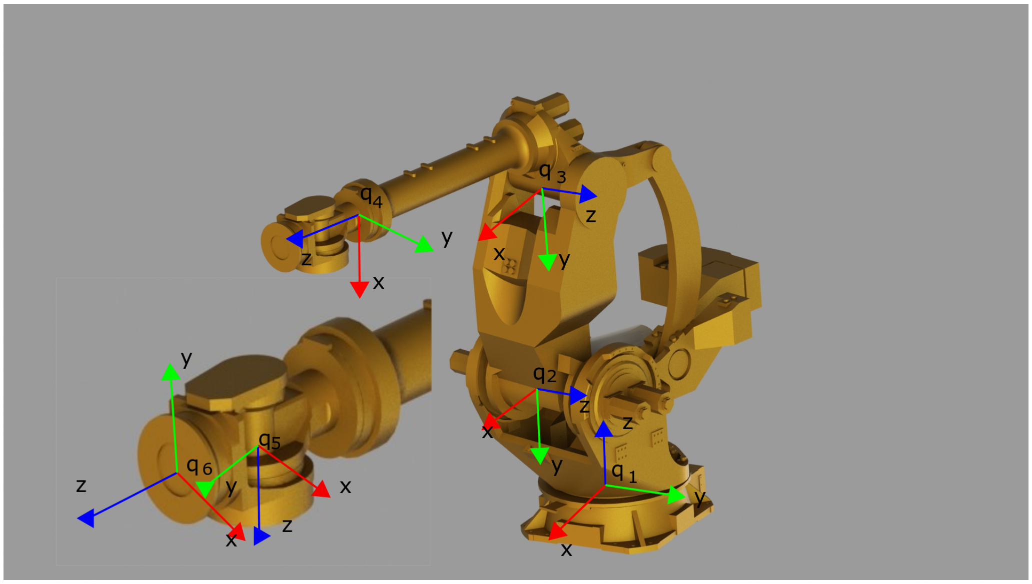

Robotic arm

1 Jacobian for 3 Degrees

The Denavit -Hartemberg parameters

θ_i	d_i	a_i	α_i
$\theta_1 = -q_1$	$d_1 = 1134mm$	$a_1 = -658.07mm$	$\alpha_1 = -\frac{\pi}{2}$
$\theta_2 = -q_2$	$d_2 = 0mm$	$a_2 = -1689.31mm$	$\alpha_2 = 0$
$\theta_3 = \frac{\pi}{2} + q_3$	$d_3 = 367.5mm$	$a_3 = 2128.98mm$	$\alpha_3 = \frac{\pi}{2}$
$\theta_4 = \frac{\pi}{2} + q_4$	$d_4 = 0$	$a_4 = 353.87mm$	$\alpha_4 = \frac{\pi}{2}$
$\theta_5 = q_5$	$d_5 = 0$	$a_5 = 452mm$	$\alpha_5 = \frac{\pi}{2}$

The transformation between each framework

$$A_{01} = \begin{pmatrix} \text{Cos}[q_1] & 0 & \text{Sin}[q_1] & -658.07\text{Cos}[q_1] \\ -\text{Sin}[q_1] & 0 & \text{Cos}[q_1] & 658.07\text{Sin}[q_1] \\ 0 & -1 & 0 & 1134 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

$$A_{12} = \begin{pmatrix} \text{Cos}[q_2] & \text{Sin}[q_2] & 0 & -1689.31\text{Cos}[q_2] \\ -\text{Sin}[q_2] & \text{Cos}[q_2] & 0 & 1689.31\text{Sin}[q_2] \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

$$A_{23} = \begin{pmatrix} -\text{Sin}[q_3] & 0 & \text{Cos}[q_3] & 2128.98\text{Sin}[q_3] \\ \text{Cos}[q_3] & 0 & \text{Sin}[q_3] & -2128.98\text{Cos}[q_3] \\ 0 & 1 & 0 & 367.5 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

The complete transformation is given by

$$A03 = \begin{pmatrix} & & & Px \\ & R & & Py \\ & & & Pz \\ 0. & 0. & 0. & 1. \end{pmatrix}$$

$$Px = 367.5\text{Sin}[q_1] + \text{Cos}[q_1](-658.07 - 2128.98\text{Cos}[q_3]\text{Sin}[q_2] + \text{Cos}[q_2](-1689.31 + 2128.98\text{Sin}[q_3]))$$

$$Py = 367.5\text{Cos}[q_1] + \text{Sin}[q_1](658.07 + 2128.98\text{Cos}[q_3]\text{Sin}[q_2] + \text{Cos}[q_2](1689.31 - 2128.98\text{Sin}[q_3]))$$

$$Pz = 1134. + 2128.98\text{Cos}[q_2]\text{Cos}[q_3] + \text{Sin}[q_2](-1689.31 + 2128.98\text{Sin}[q_3])$$

$$R = \begin{pmatrix} \text{Cos}[q_1]\text{Sin}[q_2 - q_3] & \text{Sin}[q_1] & \text{Cos}[q_1]\text{Cos}[q_2 - q_3] \\ -\text{Sin}[q_1]\text{Sin}[q_2 - q_3] & \text{Cos}[q_1] & -\text{Cos}[q_2 - q_3]\text{Sin}[q_1] \\ -\text{Cos}[q_2 - q_3] & 0. & \text{Sin}[q_2 - q_3] \end{pmatrix}$$

The obtained Jacobian is given by

$$J = \begin{bmatrix} J_v \\ J_\omega \end{bmatrix} \tag{1}$$

$$J_v = \begin{bmatrix} \frac{\partial Px}{\partial q_1} & \frac{\partial Px}{\partial q_2} & \frac{\partial Px}{\partial q_3} \\ \frac{\partial Py}{\partial q_1} & \frac{\partial Py}{\partial q_2} & \frac{\partial Py}{\partial q_3} \\ \frac{\partial Pz}{\partial q_1} & \frac{\partial Pz}{\partial q_2} & \frac{\partial Pz}{\partial q_3} \end{bmatrix} \tag{2}$$

$$J_\omega = \begin{bmatrix} \omega_{x1} & \omega_{x2} & \omega_{x3} \\ \omega_{y1} & \omega_{y2} & \omega_{y3} \\ \omega_{z1} & \omega_{z2} & \omega_{z3} \end{bmatrix} \tag{3}$$

$\frac{\partial Px}{\partial q_1} = 367.5\mathrm{Cos}\left[q_1\right] + \mathrm{Sin}\left[q_1\right]\left(658.07\ + 1689.31\mathrm{Cos}\left[q_2\right] + 2128.98\mathrm{Sin}\left[q_2 - q_3\right]\right)$

$\frac{\partial Px}{\partial q_2} = \mathrm{Cos}\left[q_1\right]\left(-2128.98\mathrm{Cos}\left[q_2 - q_3\right] + 1689.31\mathrm{Sin}\left[q_2\right]\right)$

$\frac{\partial Px}{\partial q_3} = 2128.98\mathrm{Cos}\left[q_1\right]\mathrm{Cos}\left[q_2 - q_3\right]$

$\frac{\partial Py}{\partial q_1} = -367.5\mathrm{Sin}\left[q_1\right] + \mathrm{Cos}\left[q_1\right]\left(658.07\ + 1689.31\mathrm{Cos}\left[q_2\right] + 2128.98\mathrm{Sin}\left[q_2 - q_3\right]\right)$

$\frac{\partial Py}{\partial q_2} = \mathrm{Sin}\left[q_1\right]\left(2128.98\mathrm{Cos}\left[q_2 - q_3\right] - 1689.31\mathrm{Sin}\left[q_2\right]\right)$

$\frac{\partial Py}{\partial q_3} = -2128.98\mathrm{Cos}\left[q_2 - q_3\right]\mathrm{Sin}\left[q_1\right]$

$\frac{\partial Pz}{\partial q_1} = 0$

$\frac{\partial Pz}{\partial q_2} = -1689.31\mathrm{Cos}\left[q_2\right] - 2128.98\mathrm{Sin}\left[q_2 - q_3\right]$

$\frac{\partial Pz}{\partial q_3} = 2128.98\mathrm{Sin}\left[q_2 - q_3\right]$

$$J_\omega = \begin{bmatrix} 0 & -\mathrm{Sin}\left[q_1\right] & \mathrm{Sin}\left[q_1\right] \\ 0 & -\mathrm{Cos}\left[q_1\right] & \mathrm{Cos}\left[q_1\right] \\ -1 & 0 & 0 \end{bmatrix}$$

2 Jacobian for 6 degrees

For the Jacobian with the 6 degree of freedom the transformation between the rest of frameworks are

$$A_{34} = \begin{pmatrix} -\mathrm{Sin}\left[q_4\right] & 0 & \mathrm{Cos}\left[q_4\right] & -353.87\mathrm{Sin}\left[q_4\right] \\ \mathrm{Cos}\left[q_4\right] & 0 & \mathrm{Sin}\left[q_4\right] & 353.87\mathrm{Cos}\left[q_4\right] \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

$$A_{45} = \begin{pmatrix} \mathrm{Cos}\,[q_5] & 0 & -\mathrm{Sin}\,[q_5] & -452\mathrm{Cos}\,[q_5] \\ \mathrm{Sin}\,[q_5] & 0 & \mathrm{Cos}\,[q_5] & -452\mathrm{Sin}\,[q_5] \\ 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

$$A03 = \begin{pmatrix} & & & Px \\ & R & & Py \\ & & & Pz \\ 0. & 0. & 0. & 1. \end{pmatrix}$$

where

$$\begin{aligned} Px &= (367.5 + \mathrm{Cos}\,[q_4]\,(353.87\ - 452.\mathrm{Cos}\,[q_5]))\,\mathrm{Sin}\,[q_1] \\ &\quad -658.07\mathrm{Cos}\,[q_1] \\ &\quad +\mathrm{Cos}\,[q_1]\,\mathrm{Cos}\,[q_3]\,\mathrm{Sin}\,[q_2]\,(-2128.98 - 353.87\mathrm{Sin}\,[q_4]) \\ &\quad +\mathrm{Cos}\,[q_1]\,452.\mathrm{Cos}\,[q_5]\,\mathrm{Sin}\,[q_2 - q_3]\,\mathrm{Sin}\,[q_4] \\ &\quad +\mathrm{Cos}\,[q_1]\,(\mathrm{Cos}\,[q_2]\,(-1689.31 + \mathrm{Sin}\,[q_3]\,(2128.98\ + 353.87\mathrm{Sin}\,[q_4])) - 452.\mathrm{Cos}\,[q_2 - q_3]\,\mathrm{Sin}\,[q_5]) \end{aligned}$$

$$\begin{aligned} Py &= \mathrm{Cos}\,[q_1]\,(367.5\ + \mathrm{Cos}\,[q_4]\,(353.87\ - 452.\mathrm{Cos}\,[q_5])) \\ &\quad +\mathrm{Sin}\,[q_1]\,(658.07 + \mathrm{Cos}\,[q_2]\,(1689.31\ + \mathrm{Sin}\,[q_3]\,(-2128.98 - 353.87\mathrm{Sin}\,[q_4]))) \\ &\quad -\mathrm{Sin}\,[q_1]\,(452.\mathrm{Cos}\,[q_5]\,\mathrm{Sin}\,[q_2 - q_3]\,\mathrm{Sin}\,[q_4]) \\ &\quad \mathrm{Sin}\,[q_1]\,(+\mathrm{Cos}\,[q_3]\,\mathrm{Sin}\,[q_2]\,(2128.98\ + 353.87\mathrm{Sin}\,[q_4]) + 452.\mathrm{Cos}\,[q_2 - q_3]\,\mathrm{Sin}\,[q_5]) \end{aligned}$$

$$\begin{aligned} Pz &= 1,134.0002 \\ &\quad -452\mathrm{Sin}\,[q_2]\,(3.73741\ + \mathrm{Sin}\,[q_3]\,(-4.71013 + (-0.782898 + \mathrm{Cos}\,[q_5])\,\mathrm{Sin}\,[q_4]) + \mathrm{Cos}\,[q_3]\,\mathrm{Sin}\,[q_5]) \\ &\quad -452.\,(\mathrm{Cos}\,[q_2]\,(\mathrm{Cos}\,[q_3]\,(-4.71013 + (-0.782898 + \mathrm{Cos}\,[q_5])\,\mathrm{Sin}\,[q_4]) - 1.\mathrm{Sin}\,[q_3]\,\mathrm{Sin}\,[q_5])) \end{aligned}$$

$$R = \begin{bmatrix} r_{11} & r_{12} & r_{13} \\ r_{21} & r_{22} & r_{23} \\ r_{31} & r_{32} & r_{33} \end{bmatrix}$$

$$
\begin{aligned}
r_{11} &= \mathrm{Cos}\,[q_4]\,\mathrm{Cos}\,[q_5]\,\mathrm{Sin}\,[q_1] + \mathrm{Cos}\,[q_1]\,(-\mathrm{Cos}\,[q_5]\,\mathrm{Sin}\,[q_2 - q_3]\,\mathrm{Sin}\,[q_4] + \mathrm{Cos}\,[q_2 - q_3]\,\mathrm{Sin}\,[q_5]) \\
r_{12} &= -\mathrm{Cos}\,[q_1]\,\mathrm{Cos}\,[q_4]\,\mathrm{Sin}\,[q_2 - q_3] - \mathrm{Sin}\,[q_1]\,\mathrm{Sin}\,[q_4] \\
r_{13} &= -\mathrm{Cos}\,[q_4]\,\mathrm{Sin}\,[q_1]\,\mathrm{Sin}\,[q_5] + \mathrm{Cos}\,[q_1]\,(\mathrm{Cos}\,[q_2 - q_3]\,\mathrm{Cos}\,[q_5] + \mathrm{Sin}\,[q_2 - q_3]\,\mathrm{Sin}\,[q_4]\,\mathrm{Sin}\,[q_5]) \\
r_{21} &= \mathrm{Cos}\,[q_1]\,\mathrm{Cos}\,[q_4]\,\mathrm{Cos}\,[q_5] + \mathrm{Sin}\,[q_1]\,(\mathrm{Cos}\,[q_5]\,\mathrm{Sin}\,[q_2 - q_3]\,\mathrm{Sin}\,[q_4] - \mathrm{Cos}\,[q_2 - q_3]\,\mathrm{Sin}\,[q_5]) \\
r_{22} &= \mathrm{Cos}\,[q_4]\,\mathrm{Sin}\,[q_1]\,\mathrm{Sin}\,[q_2 - q_3] - \mathrm{Cos}\,[q_1]\,\mathrm{Sin}\,[q_4] \\
r_{23} &= -\mathrm{Cos}\,[q_2 - q_3]\,\mathrm{Cos}\,[q_5]\,\mathrm{Sin}\,[q_1] - (\mathrm{Cos}\,[q_1]\,\mathrm{Cos}\,[q_4] + \mathrm{Sin}\,[q_1]\,\mathrm{Sin}\,[q_2 - q_3]\,\mathrm{Sin}\,[q_4])\,\mathrm{Sin}\,[q_5] \\
r_{31} &= \mathrm{Cos}\,[q_2 - q_3]\,\mathrm{Cos}\,[q_5]\,\mathrm{Sin}\,[q_4] + \mathrm{Sin}\,[q_2 - q_3]\,\mathrm{Sin}\,[q_5] \\
r_{32} &= \mathrm{Cos}\,[q_2 - q_3]\,\mathrm{Cos}\,[q_4] \\
r_{33} &= \mathrm{Cos}\,[q_5]\,\mathrm{Sin}\,[q_2 - q_3] - \mathrm{Cos}\,[q_2 - q_3]\,\mathrm{Sin}\,[q_4]\,\mathrm{Sin}\,[q_5]
\end{aligned}
$$

The obtained Jacobian is given by

$$
J = \begin{bmatrix} J_v \\ J_\omega \end{bmatrix} \tag{4}
$$

$$
J_v = \begin{bmatrix} \frac{\partial Px}{\partial q_1} & \frac{\partial Px}{\partial q_2} & \frac{\partial Px}{\partial q_3} \\ \frac{\partial Py}{\partial q_1} & \frac{\partial Py}{\partial q_2} & \frac{\partial Py}{\partial q_3} \\ \frac{\partial Pz}{\partial q_1} & \frac{\partial Pz}{\partial q_2} & \frac{\partial Pz}{\partial q_3} \end{bmatrix} \tag{5}
$$

$$
J_\omega = \begin{bmatrix} \omega_{x1} & \omega_{x2} & \omega_{x3} \\ \omega_{y1} & \omega_{y2} & \omega_{y3} \\ \omega_{z1} & \omega_{z2} & \omega_{z3} \end{bmatrix} \tag{6}
$$

$$
\begin{aligned}
\frac{\partial Px}{\partial q_1} = {} & \mathrm{Cos}\,[q_1]\,(367.5 + \mathrm{Cos}\,[q_4]\,(353.87 - 452.\mathrm{Cos}\,[q_5])) \\
& +\mathrm{Sin}\,[q_1]\,(658.07 + \mathrm{Cos}\,[q_2]\,(1689.31 + \mathrm{Sin}\,[q_3]\,(-2128.98 - 353.87\mathrm{Sin}\,[q_4]))) \\
& +\mathrm{Sin}\,[q_1]\,(-452.\mathrm{Cos}\,[q_5]\,\mathrm{Sin}\,[q_2 - q_3]\,\mathrm{Sin}\,[q_4] + \mathrm{Cos}\,[q_3]\,\mathrm{Sin}\,[q_2]\,(2128.98 + 353.87\mathrm{Sin}\,[q_4])) \\
& +\mathrm{Sin}\,[q_1]\,(452.\mathrm{Cos}\,[q_2 - q_3]\,\mathrm{Sin}\,[q_5])
\end{aligned}
$$

$$
\begin{aligned}
\frac{\partial Px}{\partial q_2} = {} & 353.87\mathrm{Cos}\,[q_1]\,(\mathrm{Sin}\,[q_2]\,(4.77382 + \mathrm{Sin}\,[q_3]\,(-6.01628 - 1.\mathrm{Sin}\,[q_4]))) \\
& +353.87\mathrm{Cos}\,[q_1]\,(\mathrm{Cos}\,[q_2]\,\mathrm{Cos}\,[q_3]\,(-6.01628 - 1.\mathrm{Sin}\,[q_4])) \\
& +353.87\mathrm{Cos}\,[q_1]\,(+1.27731\mathrm{Cos}\,[q_2 - q_3]\,\mathrm{Cos}\,[q_5]\,\mathrm{Sin}\,[q_4] + 1.27731\mathrm{Sin}\,[q_2 - q_3]\,\mathrm{Sin}\,[q_5])
\end{aligned}
$$

$$
\begin{aligned}
\frac{\partial Px}{\partial q_3} = {} & 353.87\mathrm{Cos}\,[q_1]\,(-1.27731\mathrm{Cos}\,[q_2 - q_3]\,\mathrm{Cos}\,[q_5]\,\mathrm{Sin}\,[q_4] + \mathrm{Cos}\,[q_2]\,\mathrm{Cos}\,[q_3]\,(6.01628 + 1.\mathrm{Sin}\,[q_4])) \\
& +353.87\mathrm{Cos}\,[q_1]\,(\mathrm{Sin}\,[q_2]\,\mathrm{Sin}\,[q_3]\,(6.01628 + 1.\mathrm{Sin}\,[q_4]) - 1.27731\mathrm{Sin}\,[q_2 - q_3]\,\mathrm{Sin}\,[q_5])
\end{aligned}
$$

$\frac{\partial Px}{\partial q_4} = \mathrm{Cos}[q_1]\,\mathrm{Cos}[q_4]\,(-353.87\mathrm{Cos}[q_3]\,\mathrm{Sin}[q_2] + 452.\mathrm{Cos}[q_5]\,\mathrm{Sin}[q_2 - q_3] + 353.87\mathrm{Cos}[q_2]\,\mathrm{Sin}[q_3])+$
$(-353.87 + 452.\mathrm{Cos}[q_5])\,\mathrm{Sin}[q_1]\,\mathrm{Sin}[q_4]$

$\frac{\partial Px}{\partial q_5} = 452.\mathrm{Cos}[q_4]\,\mathrm{Sin}[q_1]\,\mathrm{Sin}[q_5]+\mathrm{Cos}[q_1]\,(-452.\mathrm{Cos}[q_2 - q_3]\,\mathrm{Cos}[q_5] - 452.\mathrm{Sin}[q_2 - q_3]\,\mathrm{Sin}[q_4]\,\mathrm{Sin}[q_5])$

$$\begin{aligned}\frac{\partial Py}{\partial q_1} \quad = \quad & (-367.5 + \mathrm{Cos}[q_4]\,(-353.87 + 452.\mathrm{Cos}[q_5]))\,\mathrm{Sin}[q_1] \\ & +\mathrm{Cos}[q_1]\,(658.07 + \mathrm{Cos}[q_2]\,(1689.31 + \mathrm{Sin}[q_3]\,(-2128.98 - 353.87\mathrm{Sin}[q_4]))) \\ & +\mathrm{Cos}[q_1]\,(-452.\mathrm{Cos}[q_5]\,\mathrm{Sin}[q_2 - q_3]\,\mathrm{Sin}[q_4] + \mathrm{Cos}[q_3]\,\mathrm{Sin}[q_2]\,(2128.98 + 353.87\mathrm{Sin}[q_4])) \\ & +\mathrm{Cos}[q_1]\,(+452.\mathrm{Cos}[q_2 - q_3]\,\mathrm{Sin}[q_5])\end{aligned}$$

$$\begin{aligned}\frac{\partial Py}{\partial q_2} \quad = \quad & -353.87\mathrm{Sin}[q_1]\,(\mathrm{Sin}[q_2]\,(4.77382 + \mathrm{Sin}[q_3]\,(-6.01628 - 1.\mathrm{Sin}[q_4]))) \\ & -353.87\mathrm{Sin}[q_1]\,(\mathrm{Cos}[q_2]\,\mathrm{Cos}[q_3]\,(-6.01628 - 1.\mathrm{Sin}[q_4]) + 1.27731\mathrm{Cos}[q_2 - q_3]\,\mathrm{Cos}[q_5]\,\mathrm{Sin}[q_4]) \\ & -353.87\mathrm{Sin}[q_1]\,(+1.27731\mathrm{Sin}[q_2 - q_3]\,\mathrm{Sin}[q_5])\end{aligned}$$

$$\begin{aligned}\frac{\partial Py}{\partial q_3} \quad = \quad & -353.87\mathrm{Sin}[q_1]\,(-1.27731\mathrm{Cos}[q_2 - q_3]\,\mathrm{Cos}[q_5]\,\mathrm{Sin}[q_4] + \mathrm{Cos}[q_2]\,\mathrm{Cos}[q_3]\,(6.01628 + 1.\mathrm{Sin}[q_4])) \\ & -353.87\mathrm{Sin}[q_1]\,(+\mathrm{Sin}[q_2]\,\mathrm{Sin}[q_3]\,(6.01628 + 1.\mathrm{Sin}[q_4]) - 1.27731\mathrm{Sin}[q_2 - q_3]\,\mathrm{Sin}[q_5])\end{aligned}$$

$\frac{\partial Py}{\partial q_4} = \mathrm{Cos}[q_4]\,\mathrm{Sin}[q_1]\,(353.87\mathrm{Cos}[q_3]\,\mathrm{Sin}[q_2] - 452.\mathrm{Cos}[q_5]\,\mathrm{Sin}[q_2 - q_3] - 353.87\mathrm{Cos}[q_2]\,\mathrm{Sin}[q_3])+$
$452.\mathrm{Cos}[q_1]\,(-0.782898 + \mathrm{Cos}[q_5])\,\mathrm{Sin}[q_4]$

$\frac{\partial Py}{\partial q_5} = 452.\mathrm{Cos}[q_2 - q_3]\,\mathrm{Cos}[q_5]\,\mathrm{Sin}[q_1]+(452.\mathrm{Cos}[q_1]\,\mathrm{Cos}[q_4] + 452.\mathrm{Sin}[q_1]\,\mathrm{Sin}[q_2 - q_3]\,\mathrm{Sin}[q_4])\,\mathrm{Sin}[q_5]$

$\frac{\partial Pz}{\partial q_1} = 0$

$$\begin{aligned}\frac{\partial Pz}{\partial q_2} \quad = \quad & \mathrm{Cos}[q_3]\,\mathrm{Sin}[q_2]\,(-2128.98 + (-353.87 + 452.\mathrm{Cos}[q_5])\,\mathrm{Sin}[q_4]) \\ & +\mathrm{Cos}[q_2]\,(-1689.31 + \mathrm{Sin}[q_3]\,(2128.98 + (353.87 - 452.\mathrm{Cos}[q_5])\,\mathrm{Sin}[q_4])) \\ & -452.\mathrm{Cos}[q_2 - q_3]\,\mathrm{Sin}[q_5]\end{aligned}$$

$\frac{\partial Pz}{\partial q_3} = -452.\mathrm{Cos}[q_3]\,(\mathrm{Sin}[q_2]\,(-4.71013 + (-0.782898 + \mathrm{Cos}[q_5])\,\mathrm{Sin}[q_4]) - 1.\mathrm{Cos}[q_2]\,\mathrm{Sin}[q_5])+$
$452.\mathrm{Sin}[q_3]\,(\mathrm{Cos}[q_2]\,(-4.71013 + (-0.782898 + \mathrm{Cos}[q_5])\,\mathrm{Sin}[q_4]) + \mathrm{Sin}[q_2]\,\mathrm{Sin}[q_5])$

$\frac{\partial Pz}{\partial q_4} = -452.\mathrm{Cos}[q_2 - q_3]\,\mathrm{Cos}[q_4]\,(-0.782898 + \mathrm{Cos}[q_5])$

$$\frac{\partial Pz}{\partial q_5} = -452\mathrm{Cos}\left[q_3\right]\left(\mathrm{Cos}\left[q_5\right]\mathrm{Sin}\left[q_2\right]-\mathrm{Cos}\left[q_2\right]\mathrm{Sin}\left[q_4\right]\mathrm{Sin}\left[q_5\right]\right)$$
$$-452.\left(+\mathrm{Sin}\left[q_3\right]\left(-1.\mathrm{Cos}\left[q_2\right]\mathrm{Cos}\left[q_5\right]-\mathrm{Sin}\left[q_2\right]\mathrm{Sin}\left[q_4\right]\mathrm{Sin}\left[q_5\right]\right)\right)$$

$$J_\omega = \begin{pmatrix} 0 & -\mathrm{Sin}\left[q_1\right] & \mathrm{Sin}\left[q_1\right] & \mathrm{Cos}\left[q_1\right]\mathrm{Cos}\left[q_2-q_3\right] & \mathrm{Cos}\left[q_1\right]\mathrm{Cos}\left[q_4\right]\mathrm{Sin}\left[q_2-q_3\right]+\mathrm{Sin}\left[q_1\right]\mathrm{Sin}\left[q_4\right] \\ 0 & -\mathrm{Cos}\left[q_1\right] & \mathrm{Cos}\left[q_1\right] & -\mathrm{Cos}\left[q_2-q_3\right]\mathrm{Sin}\left[q_1\right] & -\mathrm{Cos}\left[q_4\right]\mathrm{Sin}\left[q_1\right]\mathrm{Sin}\left[q_2-q_3\right]+\mathrm{Cos}\left[q_1\right]\mathrm{Sin}\left[q_4\right] \\ -1 & 0 & 0 & \mathrm{Sin}\left[q_2-q_3\right] & -\mathrm{Cos}\left[q_2-q_3\right]\mathrm{Cos}\left[q_4\right] \end{pmatrix}$$