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ОЦЕНИВАНИЕ ПАРАМЕТРОВ РОБОТА-МАНИПУЛЯТОРА KUKA YOUBOT[1)]

Предложен новый алгоритм оценивания параметров механических параметров динамической модели робота.

1. Введение

Здесь надо что-то написать, но я пока не придумал, что.

2. Тест

$W_s(1,1) = 0$

$W_s(1,2) = 0$

$W_s(1,3) = 0$

$W_s(1,4) = 0$

$W_s(1,5) = 0$

$W_s(2,1) = 0$

$W_s(2,2) = 0$

$W_s(2,3) = 0$

$W_s(2,4) = 0$

$W_s(2,5) = 0$

1)

$$W_s(3,1) = 0$$

$$W_s(3,2) = 0$$

$$W_s(3,3) = 0$$

$$W_s(3,4) = 0$$

$$W_s(3,5) = 0$$

$$W_s(4,1) = 0$$

$$W_s(4,2) = 0$$

$$W_s(4,3) = 0$$

$$W_s(4,4) = 0$$

$$W_s(4,5) = 0$$

$$W_s(5,1) = 0$$

$$W_s(5,2) = 0$$

$$W_s(5,3) = 0$$

$$W_s(5,4) = 0$$

$$W_s(5,5) = 0$$

$$W_s(6,1) = 0$$

$$W_s(6,2) = -\cos(\alpha 2) * \sin(\alpha 1) * \sin(q2)$$

$$W_s(6,3) = 0$$

$$W_s(6,4) = 0$$

$$W_s(6,5) = 0$$

$$W_s(7,1) = 0$$

$$W_s(7,2) = 1.0 * \sin(\alpha 1) * \sin(\alpha 2) * \sin(q2)$$

$W_s(7,3) = 0$

$W_s(7,4) = 0$

$W_s(7,5) = 0$

$W_s(8,1) = 0$

$W_s(8,2) = a2 * \cos(q2) * \sin(\alpha 1)$

$W_s(8,3) = 0$

$W_s(8,4) = 0$

$W_s(8,5) = 0$

$W_s(9,1) = 0$

$W_s(9,2) = 0$

$W_s(9,3) = \cos(q3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q2) * \sin(\alpha 1)) - \sin(\alpha 1) * \sin(q2) * \sin(q3)$

$W_s(9,4) = 0$

$W_s(9,5) = 0$

$W_s(10,1) = 0$

$W_s(10,2) = 1.0 * \sin(\alpha 1) * \sin(\alpha 2) * \sin(\alpha 3) * \sin(q2) - 1.0 * \cos(\alpha 3) * \cos(q2) * \sin(\alpha 1) * \sin(q3) - \cos(\alpha 2) * \cos(\alpha 3) * \cos(q3) * \sin(\alpha 1) * \sin(q2)$

$W_s(10,3) = -\cos(\alpha 3) * \sin(q3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q2) * \sin(\alpha 1)) - 1.0 * \cos(\alpha 3) * \cos(q3) * \sin(\alpha 1) * \sin(q2)$

$W_s(10,4) = 0$

$W_s(10,5) = 0$

$W_s(11,1) = 0$

$W_s(11,2) = 1.0 * \cos(\alpha 3) * \sin(\alpha 1) * \sin(\alpha 2) * \sin(q2) + \cos(q2) * \sin(\alpha 1) * \sin(\alpha 3) * \sin(q3) + 1.0 * \cos(\alpha 2) * \cos(q3) * \sin(\alpha 1) * \sin(\alpha 3) * \sin(q2)$

$W_s(11,3) = 1.0 * \sin(\alpha 3) * \sin(q3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q2) * \sin(\alpha 1)) + \cos(q3) * \sin(\alpha 1) * \sin(\alpha 3) * \sin(q2)$

$W_s(11,4) = 0$

$W_s(11,5) = 0$

$W_s(12,1) = 0$

$W_s(12,2) = a2 * \cos(q2) * \sin(\alpha 1) + a3 * \cos(q2) * \cos(q3) * \sin(\alpha 1) + 1.0 * d3 * \sin(\alpha 1) * \sin(\alpha 2) * \sin(q2) - a3 * \cos(\alpha 2) * \sin(\alpha 1) * \sin(q2) * \sin(q3)$

$W_s(12,3) = a3 * \cos(q3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q2) * \sin(\alpha 1)) - a3 * \sin(\alpha 1) * \sin(q2) * \sin(q3)$

$W_s(12,4) = 0$

$W_s(12,5) = 0$

$W_s(13,1) = 0$

$W_s(13,2) = 0$

$W_s(13,3) = d4 * (1.0 * \sin(\alpha 3) * \sin(q3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q2) * \sin(\alpha 1)) + \cos(q3) * \sin(\alpha 1) * \sin(\alpha 3) * \sin(q2)) - \sin(q4) * (\cos(\alpha 3) * \sin(q3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q2) * \sin(\alpha 1)) + 1.0 * \cos(\alpha 3) * \cos(q3) * \sin(\alpha 1) * \sin(q2)) + \cos(q4) * (\cos(q3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q2) * \sin(\alpha 1)) - \sin(\alpha 1) * \sin(q2) * \sin(q3)) - a4 * \sin(q4) * (\cos(\alpha 3) * \sin(q3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q2) * \sin(\alpha 1)) + 1.0 * \cos(\alpha 3) * \cos(q3) * \sin(\alpha 1) * \sin(q2)) + a4 * \cos(q4) * (\cos(q3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q2) * \sin(\alpha 1)) - \sin(\alpha 1) * \sin(q2) * \sin(q3)) + a3 * \cos(q3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q2) * \sin(\alpha 1)) - a3 * \sin(\alpha 1) * \sin(q2) * \sin(q3)$

$$W_s(13,4) = \cos(q4) * (\sin(\alpha3) * (\cos(\alpha1) * \cos(\alpha2) - 1.0 * \cos(q2) * \sin(\alpha1) * \sin(\alpha2)) + \cos(\alpha3) * \cos(q3) * (\cos(\alpha1) * \sin(\alpha2) + \cos(\alpha2) * \cos(q2) * \sin(\alpha1)) - 1.0 * \cos(\alpha3) * \sin(\alpha1) * \sin(q2) * \sin(q3)) - \sin(q4) * (\sin(q3) * (\cos(\alpha1) * \sin(\alpha2) + \cos(\alpha2) * \cos(q2) * \sin(\alpha1)) + \cos(q3) * \sin(\alpha1) * \sin(q2)) - a4 * \sin(q4) * (\sin(q3) * (\cos(\alpha1) * \sin(\alpha2) + \cos(\alpha2) * \cos(q2) * \sin(\alpha1)) + \cos(q3) * \sin(\alpha1) * \sin(q2)) + a4 * \cos(q4) * (\sin(\alpha3) * (\cos(\alpha1) * \cos(\alpha2) - 1.0 * \cos(q2) * \sin(\alpha1) * \sin(\alpha2)) + \cos(\alpha3) * \cos(q3) * (\cos(\alpha1) * \sin(\alpha2) + \cos(\alpha2) * \cos(q2) * \sin(\alpha1)) - 1.0 * \cos(\alpha3) * \sin(\alpha1) * \sin(q2) * \sin(q3))$$

$$W_s(13,5) = 0$$

$$W_s(14,1) = 0$$

$$W_s(14,2) = \sin(\alpha4) * (1.0 * \cos(\alpha3) * \sin(\alpha1) * \sin(\alpha2) * \sin(q2) + \cos(q2) * \sin(\alpha1) * \sin(\alpha3) * \sin(q3) + 1.0 * \cos(\alpha2) * \cos(q3) * \sin(\alpha1) * \sin(\alpha3) * \sin(q2)) + d4 * (1.0 * \cos(\alpha3) * \sin(\alpha1) * \sin(\alpha2) * \sin(q2) + \cos(q2) * \sin(\alpha1) * \sin(\alpha3) * \sin(q3) + 1.0 * \cos(\alpha2) * \cos(q3) * \sin(\alpha1) * \sin(\alpha3) * \sin(q2)) - 1.0 * \cos(\alpha4) * \sin(q4) * (\cos(q2) * \cos(q3) * \sin(\alpha1) - \cos(\alpha2) * \sin(\alpha1) * \sin(q2) * \sin(q3)) - \cos(\alpha4) * \cos(q4) * (1.0 * \cos(\alpha3) * \cos(q2) * \sin(\alpha1) * \sin(q3) - 1.0 * \sin(\alpha1) * \sin(\alpha2) * \sin(\alpha3) * \sin(q2) + \cos(\alpha2) * \cos(\alpha3) * \cos(q3) * \sin(\alpha1) * \sin(q2)) + a2 * \cos(q2) * \sin(\alpha1) + a4 * \cos(q4) * (\cos(q2) * \cos(q3) * \sin(\alpha1) - \cos(\alpha2) * \sin(\alpha1) * \sin(q2) * \sin(q3)) - a4 * \sin(q4) * (1.0 * \cos(\alpha3) * \cos(q2) * \sin(\alpha1) * \sin(q3) - 1.0 * \sin(\alpha1) * \sin(\alpha2) * \sin(\alpha3) * \sin(q2) + \cos(\alpha2) * \cos(\alpha3) * \cos(q3) * \sin(\alpha1) * \sin(q2)) + a3 * \cos(q2) * \cos(q3) * \sin(\alpha1) + 1.0 * d3 * \sin(\alpha1) * \sin(\alpha2) * \sin(q2) - a3 * \cos(\alpha2) * \sin(\alpha1) * \sin(q2) * \sin(q3)$$

$$W_s(14,3) = d4 * (1.0 * \sin(\alpha3) * \sin(q3) * (\cos(\alpha1) * \sin(\alpha2) + \cos(\alpha2) * \cos(q2) * \sin(\alpha1)) + \cos(q3) * \sin(\alpha1) * \sin(\alpha3) * \sin(q2)) + \sin(\alpha4) * (1.0 * \sin(\alpha3) * \sin(q3) * (\cos(\alpha1) * \sin(\alpha2) + \cos(\alpha2) * \cos(q2) * \sin(\alpha1)) + \cos(q3) * \sin(\alpha1) * \sin(\alpha3) * \sin(q2)) - a4 * \sin(q4) * (\cos(\alpha3) * \sin(q3) * (\cos(\alpha1) * \sin(\alpha2) + \cos(\alpha2) * \cos(q2) * \sin(\alpha1)) + 1.0 * \cos(\alpha3) * \cos(q3) * \sin(\alpha1) *$$

$\sin(q2)) + a4 * \cos(q4) * (\cos(q3) * (\cos(\alpha1) * \sin(\alpha2) + \cos(\alpha2) * \cos(q2) * \sin(\alpha1)) - \sin(\alpha1) * \sin(q2) * \sin(q3)) - \cos(\alpha4) * \cos(q4) * (\cos(\alpha3) * \sin(q3) * (\cos(\alpha1) * \sin(\alpha2) + \cos(\alpha2) * \cos(q2) * \sin(\alpha1)) + 1.0 * \cos(\alpha3) * \cos(q3) * \sin(\alpha1) * \sin(q2)) + a3 * \cos(q3) * (\cos(\alpha1) * \sin(\alpha2) + \cos(\alpha2) * \cos(q2) * \sin(\alpha1)) - 1.0 * \cos(\alpha4) * \sin(q4) * (\cos(q3) * (\cos(\alpha1) * \sin(\alpha2) + \cos(\alpha2) * \cos(q2) * \sin(\alpha1)) - \sin(\alpha1) * \sin(q2) * \sin(q3)) - a3 * \sin(\alpha1) * \sin(q2) * \sin(q3)$

$W_s(14, 4) = a4 * \cos(q4) * (\sin(\alpha3) * (\cos(\alpha1) * \cos(\alpha2) - 1.0 * \cos(q2) * \sin(\alpha1) * \sin(\alpha2)) + \cos(\alpha3) * \cos(q3) * (\cos(\alpha1) * \sin(\alpha2) + \cos(\alpha2) * \cos(q2) * \sin(\alpha1)) - 1.0 * \cos(\alpha3) * \sin(\alpha1) * \sin(q2) * \sin(q3)) - a4 * \sin(q4) * (\sin(q3) * (\cos(\alpha1) * \sin(\alpha2) + \cos(\alpha2) * \cos(q2) * \sin(\alpha1)) + \cos(q3) * \sin(\alpha1) * \sin(q2)) - 1.0 * \cos(\alpha4) * \cos(q4) * (\sin(q3) * (\cos(\alpha1) * \sin(\alpha2) + \cos(\alpha2) * \cos(q2) * \sin(\alpha1)) + \cos(q3) * \sin(\alpha1) * \sin(q2)) - \cos(\alpha4) * \sin(q4) * (\sin(\alpha3) * (\cos(\alpha1) * \cos(\alpha2) - 1.0 * \cos(q2) * \sin(\alpha1) * \sin(\alpha2)) + \cos(\alpha3) * \cos(q3) * (\cos(\alpha1) * \sin(\alpha2) + \cos(\alpha2) * \cos(q2) * \sin(\alpha1)) - 1.0 * \cos(\alpha3) * \sin(\alpha1) * \sin(q2) * \sin(q3))$

$W_s(14, 5) = 0$

$W_s(15, 1) = 0$

$W_s(15, 2) = \cos(\alpha4) * (1.0 * \cos(\alpha3) * \sin(\alpha1) * \sin(\alpha2) * \sin(q2) + \cos(q2) * \sin(\alpha1) * \sin(\alpha3) * \sin(q3) + 1.0 * \cos(\alpha2) * \cos(q3) * \sin(\alpha1) * \sin(\alpha3) * \sin(q2)) + d4 * (1.0 * \cos(\alpha3) * \sin(\alpha1) * \sin(\alpha2) * \sin(q2) + \cos(q2) * \sin(\alpha1) * \sin(\alpha3) * \sin(q3) + 1.0 * \cos(\alpha2) * \cos(q3) * \sin(\alpha1) * \sin(\alpha3) * \sin(q2)) + \sin(\alpha4) * \sin(q4) * (\cos(q2) * \cos(q3) * \sin(\alpha1) - \cos(\alpha2) * \sin(\alpha1) * \sin(q2) * \sin(q3)) + 1.0 * \cos(q4) * \sin(\alpha4) * (1.0 * \cos(\alpha3) * \cos(q2) * \sin(\alpha1) * \sin(q3) - 1.0 * \sin(\alpha1) * \sin(\alpha2) * \sin(\alpha3) * \sin(q2) + \cos(\alpha2) * \cos(\alpha3) * \cos(q3) * \sin(\alpha1) * \sin(q2)) + a2 * \cos(q2) * \sin(\alpha1) + a4 * \cos(q4) * (\cos(q2) * \cos(q3) * \sin(\alpha1) - \cos(\alpha2) * \sin(\alpha1) * \sin(q2) * \sin(q3)) - a4 * \sin(q4) * (1.0 * \cos(\alpha3) * \cos(q2) * \sin(\alpha1) * \sin(q3) - 1.0 * \sin(\alpha1) * \sin(\alpha2) * \sin(\alpha3) * \sin(q2) + \cos(\alpha2) * \cos(\alpha3) * \cos(q3) * \sin(\alpha1) * \sin(q2)) + a3 * \cos(q2) * \cos(q3) *$

$$\sin(\alpha 1) + 1.0 * d3 * \sin(\alpha 1) * \sin(\alpha 2) * \sin(q2) - a3 * \cos(\alpha 2) * \sin(\alpha 1) * \sin(q2) * \sin(q3)$$

$$W_s(15,3) = d4*(1.0*\sin(\alpha 3)*\sin(q3)*(\cos(\alpha 1)*\sin(\alpha 2)+\cos(\alpha 2)*\cos(q2)*\sin(\alpha 1))+ \cos(q3)*\sin(\alpha 1)*\sin(\alpha 3)*\sin(q2))+\cos(\alpha 4)*(1.0*\sin(\alpha 3)*\sin(q3)*(\cos(\alpha 1)*\sin(\alpha 2)+ \cos(\alpha 2)*\cos(q2)*\sin(\alpha 1))+\cos(q3)*\sin(\alpha 1)*\sin(\alpha 3)*\sin(q2))-a4*\sin(q4)*(\cos(\alpha 3)* \sin(q3)*(\cos(\alpha 1)*\sin(\alpha 2)+\cos(\alpha 2)*\cos(q2)*\sin(\alpha 1))+1.0*\cos(\alpha 3)*\cos(q3)*\sin(\alpha 1)* \sin(q2))+a4*\cos(q4)*(\cos(q3)*(\cos(\alpha 1)*\sin(\alpha 2)+\cos(\alpha 2)*\cos(q2)*\sin(\alpha 1))-\sin(\alpha 1)* \sin(q2)*\sin(q3))+1.0*\cos(q4)*\sin(\alpha 4)*(\cos(\alpha 3)*\sin(q3)*(\cos(\alpha 1)*\sin(\alpha 2)+\cos(\alpha 2)* \cos(q2)*\sin(\alpha 1))+1.0*\cos(\alpha 3)*\cos(q3)*\sin(\alpha 1)*\sin(q2))+a3*\cos(q3)*(\cos(\alpha 1)* \sin(\alpha 2)+\cos(\alpha 2)*\cos(q2)*\sin(\alpha 1))+\sin(\alpha 4)*\sin(q4)*(\cos(q3)*(\cos(\alpha 1)*\sin(\alpha 2)+ \cos(\alpha 2)*\cos(q2)*\sin(\alpha 1))-\sin(\alpha 1)*\sin(q2)*\sin(q3))-a3*\sin(\alpha 1)*\sin(q2)*\sin(q3)$$

$$W_s(15,4) = 1.0*\sin(\alpha 4)*\sin(q4)*(\sin(\alpha 3)*(\cos(\alpha 1)*\cos(\alpha 2)-1.0*\cos(q2)*\sin(\alpha 1)* \sin(\alpha 2))+\cos(\alpha 3)*\cos(q3)*(\cos(\alpha 1)*\sin(\alpha 2)+\cos(\alpha 2)*\cos(q2)*\sin(\alpha 1))-1.0*\cos(\alpha 3)* \sin(\alpha 1)*\sin(q2)*\sin(q3))-a4*\sin(q4)*(\sin(q3)*(\cos(\alpha 1)*\sin(\alpha 2)+\cos(\alpha 2)*\cos(q2)* \sin(\alpha 1))+\cos(q3)*\sin(\alpha 1)*\sin(q2))+a4*\cos(q4)*(\sin(\alpha 3)*(\cos(\alpha 1)*\cos(\alpha 2)-1.0* \cos(q2)*\sin(\alpha 1)*\sin(\alpha 2))+\cos(\alpha 3)*\cos(q3)*(\cos(\alpha 1)*\sin(\alpha 2)+\cos(\alpha 2)*\cos(q2)* \sin(\alpha 1))-1.0*\cos(\alpha 3)*\sin(\alpha 1)*\sin(q2)*\sin(q3))+\cos(q4)*\sin(\alpha 4)*(\sin(q3)*(\cos(\alpha 1)* \sin(\alpha 2)+\cos(\alpha 2)*\cos(q2)*\sin(\alpha 1))+\cos(q3)*\sin(\alpha 1)*\sin(q2))$$

$$W_s(15,5) = 0$$

$$W_s(16,1) = 0$$

$$W_s(16,2) = 0$$

$$W_s(16,3) = 0$$

$$W_s(16,4) = 0$$

$$W_s(16,5) = 0$$

$W_s(17,1) = 0$

$W_s(17,2) = \cos(q5)*(\cos(q4)*(\cos(q2)*\cos(q3)*\sin(\alpha1) - \cos(\alpha2)*\sin(\alpha1)*\sin(q2)*\sin(q3)) - \sin(q4)*(1.0*\cos(\alpha3)*\cos(q2)*\sin(\alpha1)*\sin(q3) - 1.0*\sin(\alpha1)*\sin(\alpha2)*\sin(\alpha3)*\sin(q2) + \cos(\alpha2)*\cos(\alpha3)*\cos(q3)*\sin(\alpha1)*\sin(q2))) - \sin(q5)*(1.0*\cos(\alpha4)*\sin(q4)*(\cos(q2)*\cos(q3)*\sin(\alpha1) - \cos(\alpha2)*\sin(\alpha1)*\sin(q2)*\sin(q3)) - \sin(\alpha4)*(1.0*\cos(\alpha3)*\sin(\alpha1)*\sin(\alpha2)*\sin(q2) + \cos(q2)*\sin(\alpha1)*\sin(\alpha3)*\sin(q3) + 1.0*\cos(\alpha2)*\cos(q3)*\sin(\alpha1)*\sin(\alpha3)*\sin(q2)) + \cos(\alpha4)*\cos(q4)*(1.0*\cos(\alpha3)*\cos(q2)*\sin(\alpha1)*\sin(q3) - 1.0*\sin(\alpha1)*\sin(\alpha2)*\sin(\alpha3)*\sin(q2) + \cos(\alpha2)*\cos(\alpha3)*\cos(q3)*\sin(\alpha1)*\sin(q2)))$

$W_s(17,3) = -\cos(q5)*(\sin(q4)*(\cos(\alpha3)*\sin(q3)*(\cos(\alpha1)*\sin(\alpha2) + \cos(\alpha2)*\cos(q2)*\sin(\alpha1)) + 1.0*\cos(\alpha3)*\cos(q3)*\sin(\alpha1)*\sin(q2)) - \cos(q4)*(\cos(q3)*(\cos(\alpha1)*\sin(\alpha2) + \cos(\alpha2)*\cos(q2)*\sin(\alpha1)) - \sin(\alpha1)*\sin(q2)*\sin(q3))) - \sin(q5)*(\cos(\alpha4)*\cos(q4)*(\cos(\alpha3)*\sin(q3)*(\cos(\alpha1)*\sin(\alpha2) + \cos(\alpha2)*\cos(q2)*\sin(\alpha1)) + 1.0*\cos(\alpha3)*\cos(q3)*\sin(\alpha1)*\sin(q2)) - \sin(\alpha4)*(1.0*\sin(\alpha3)*\sin(q3)*(\cos(\alpha1)*\sin(\alpha2) + \cos(\alpha2)*\cos(q2)*\sin(\alpha1)) + \cos(q3)*\sin(\alpha1)*\sin(\alpha3)*\sin(q2)) + 1.0*\cos(\alpha4)*\sin(q4)*(\cos(q3)*(\cos(\alpha1)*\sin(\alpha2) + \cos(\alpha2)*\cos(q2)*\sin(\alpha1)) - \sin(\alpha1)*\sin(q2)*\sin(q3)))$

$W_s(17,4) = \cos(q5)*(\cos(q4)*(\sin(\alpha3)*(\cos(\alpha1)*\cos(\alpha2) - 1.0*\cos(q2)*\sin(\alpha1)*\sin(\alpha2)) + \cos(\alpha3)*\cos(q3)*(\cos(\alpha1)*\sin(\alpha2) + \cos(\alpha2)*\cos(q2)*\sin(\alpha1)) - 1.0*\cos(\alpha3)*\sin(\alpha1)*\sin(q2)*\sin(q3)) - \sin(q4)*(\sin(q3)*(\cos(\alpha1)*\sin(\alpha2) + \cos(\alpha2)*\cos(q2)*\sin(\alpha1)) + \cos(q3)*\sin(\alpha1)*\sin(q2))) - \sin(q5)*(\cos(\alpha4)*\sin(q4)*(\sin(\alpha3)*(\cos(\alpha1)*\cos(\alpha2) - 1.0*\cos(q2)*\sin(\alpha1)*\sin(\alpha2)) + \cos(\alpha3)*\cos(q3)*(\cos(\alpha1)*\sin(\alpha2) + \cos(\alpha2)*\cos(q2)*\sin(\alpha1)) - 1.0*\cos(\alpha3)*\sin(\alpha1)*\sin(q2)*\sin(q3)) + 1.0*\cos(\alpha4)*\cos(q4)*(\sin(q3)*(\cos(\alpha1)*\sin(\alpha2) + \cos(\alpha2)*\cos(q2)*\sin(\alpha1)) + \cos(q3)*\sin(\alpha1)*\sin(q2)))$

$W_s(17,5) = \cos(q5)*(\sin(\alpha4)*(\cos(\alpha3)*(\cos(\alpha1)*\cos(\alpha2) - 1.0*\cos(q2)*\sin(\alpha1)*$

$\sin(\alpha 2)) - 1.0 * \cos(q3) * \sin(\alpha 3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q2) * \sin(\alpha 1)) + \sin(\alpha 1) *$
$\sin(\alpha 3) * \sin(q2) * \sin(q3)) + \cos(\alpha 4) * \cos(q4) * (\sin(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2) - 1.0 * \cos(q2) *$
$\sin(\alpha 1) * \sin(\alpha 2)) + \cos(\alpha 3) * \cos(q3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q2) * \sin(\alpha 1)) -$
$1.0 * \cos(\alpha 3) * \sin(\alpha 1) * \sin(q2) * \sin(q3)) - 1.0 * \cos(\alpha 4) * \sin(q4) * (\sin(q3) * (\cos(\alpha 1) *$
$\sin(\alpha 2) + \cos(\alpha 2) * \cos(q2) * \sin(\alpha 1)) + \cos(q3) * \sin(\alpha 1) * \sin(q2))) - \sin(q5) * (\sin(q4) *$
$(\sin(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2) - 1.0 * \cos(q2) * \sin(\alpha 1) * \sin(\alpha 2)) + \cos(\alpha 3) * \cos(q3) * (\cos(\alpha 1) *$
$\sin(\alpha 2) + \cos(\alpha 2) * \cos(q2) * \sin(\alpha 1)) - 1.0 * \cos(\alpha 3) * \sin(\alpha 1) * \sin(q2) * \sin(q3)) + \cos(q4) *$
$(\sin(q3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q2) * \sin(\alpha 1)) + \cos(q3) * \sin(\alpha 1) * \sin(q2)))$

$W_s(18, 1) = 0$

$W_s(18, 2) = \sin(\alpha 5) * (\cos(\alpha 4) * (1.0 * \cos(\alpha 3) * \sin(\alpha 1) * \sin(\alpha 2) * \sin(q2) + \cos(q2) *$
$\sin(\alpha 1) * \sin(\alpha 3) * \sin(q3) + 1.0 * \cos(\alpha 2) * \cos(q3) * \sin(\alpha 1) * \sin(\alpha 3) * \sin(q2)) + \sin(\alpha 4) *$
$\sin(q4) * (\cos(q2) * \cos(q3) * \sin(\alpha 1) - \cos(\alpha 2) * \sin(\alpha 1) * \sin(q2) * \sin(q3)) + 1.0 * \cos(q4) *$
$\sin(\alpha 4) * (1.0 * \cos(\alpha 3) * \cos(q2) * \sin(\alpha 1) * \sin(q3) - 1.0 * \sin(\alpha 1) * \sin(\alpha 2) * \sin(\alpha 3) *$
$\sin(q2) + \cos(\alpha 2) * \cos(\alpha 3) * \cos(q3) * \sin(\alpha 1) * \sin(q2))) - 1.0 * \cos(\alpha 5) * \sin(q5) * (\cos(q4) *$
$(\cos(q2) * \cos(q3) * \sin(\alpha 1) - \cos(\alpha 2) * \sin(\alpha 1) * \sin(q2) * \sin(q3)) - \sin(q4) * (1.0 * \cos(\alpha 3) *$
$\cos(q2) * \sin(\alpha 1) * \sin(q3) - 1.0 * \sin(\alpha 1) * \sin(\alpha 2) * \sin(\alpha 3) * \sin(q2) + \cos(\alpha 2) * \cos(\alpha 3) *$
$\cos(q3) * \sin(\alpha 1) * \sin(q2))) - \cos(\alpha 5) * \cos(q5) * (1.0 * \cos(\alpha 4) * \sin(q4) * (\cos(q2) * \cos(q3) *$
$\sin(\alpha 1) - \cos(\alpha 2) * \sin(\alpha 1) * \sin(q2) * \sin(q3)) - \sin(\alpha 4) * (1.0 * \cos(\alpha 3) * \sin(\alpha 1) * \sin(\alpha 2) *$
$\sin(q2) + \cos(q2) * \sin(\alpha 1) * \sin(\alpha 3) * \sin(q3) + 1.0 * \cos(\alpha 2) * \cos(q3) * \sin(\alpha 1) * \sin(\alpha 3) *$
$\sin(q2)) + \cos(\alpha 4) * \cos(q4) * (1.0 * \cos(\alpha 3) * \cos(q2) * \sin(\alpha 1) * \sin(q3) - 1.0 * \sin(\alpha 1) *$
$\sin(\alpha 2) * \sin(\alpha 3) * \sin(q2) + \cos(\alpha 2) * \cos(\alpha 3) * \cos(q3) * \sin(\alpha 1) * \sin(q2)))$

$W_s(18, 3) = \sin(\alpha 5) * (\cos(\alpha 4) * (1.0 * \sin(\alpha 3) * \sin(q3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) *$
$\cos(q2) * \sin(\alpha 1)) + \cos(q3) * \sin(\alpha 1) * \sin(\alpha 3) * \sin(q2)) + 1.0 * \cos(q4) * \sin(\alpha 4) * (\cos(\alpha 3) *$

$\sin(q3)*(\cos(\alpha1)*\sin(\alpha2)+\cos(\alpha2)*\cos(q2)*\sin(\alpha1))+1.0*\cos(\alpha3)*\cos(q3)*\sin(\alpha1)*$
$\sin(q2))+\sin(\alpha4)*\sin(q4)*(\cos(q3)*(\cos(\alpha1)*\sin(\alpha2)+\cos(\alpha2)*\cos(q2)*\sin(\alpha1))-$
$\sin(\alpha1)*\sin(q2)*\sin(q3)))+1.0*\cos(\alpha5)*\sin(q5)*(\sin(q4)*(\cos(\alpha3)*\sin(q3)*(\cos(\alpha1)*$
$\sin(\alpha2)+\cos(\alpha2)*\cos(q2)*\sin(\alpha1))+1.0*\cos(\alpha3)*\cos(q3)*\sin(\alpha1)*\sin(q2))-\cos(q4)*$
$(\cos(q3)*(\cos(\alpha1)*\sin(\alpha2)+\cos(\alpha2)*\cos(q2)*\sin(\alpha1))-\sin(\alpha1)*\sin(q2)*\sin(q3)))-$
$\cos(\alpha5)*\cos(q5)*(\cos(\alpha4)*\cos(q4)*(\cos(\alpha3)*\sin(q3)*(\cos(\alpha1)*\sin(\alpha2)+\cos(\alpha2)*\cos(q2)*$
$\sin(\alpha1))+1.0*\cos(\alpha3)*\cos(q3)*\sin(\alpha1)*\sin(q2))-\sin(\alpha4)*(1.0*\sin(\alpha3)*\sin(q3)*(\cos(\alpha1)*$
$\sin(\alpha2)+\cos(\alpha2)*\cos(q2)*\sin(\alpha1))+\cos(q3)*\sin(\alpha1)*\sin(\alpha3)*\sin(q2))+1.0*\cos(\alpha4)*$
$\sin(q4)*(\cos(q3)*(\cos(\alpha1)*\sin(\alpha2)+\cos(\alpha2)*\cos(q2)*\sin(\alpha1))-\sin(\alpha1)*\sin(q2)*\sin(q3)))$

$W_s(18,4) = \sin(\alpha5)*(1.0*\sin(\alpha4)*\sin(q4)*(\sin(\alpha3)*(\cos(\alpha1)*\cos(\alpha2)-1.0*\cos(q2)*$
$\sin(\alpha1)*\sin(\alpha2))+\cos(\alpha3)*\cos(q3)*(\cos(\alpha1)*\sin(\alpha2)+\cos(\alpha2)*\cos(q2)*\sin(\alpha1))-$
$1.0*\cos(\alpha3)*\sin(\alpha1)*\sin(q2)*\sin(q3))+\cos(q4)*\sin(\alpha4)*(\sin(q3)*(\cos(\alpha1)*\sin(\alpha2)+$
$\cos(\alpha2)*\cos(q2)*\sin(\alpha1))+\cos(q3)*\sin(\alpha1)*\sin(q2)))-\cos(\alpha5)*\cos(q5)*(\cos(\alpha4)*$
$\sin(q4)*(\sin(\alpha3)*(\cos(\alpha1)*\cos(\alpha2)-1.0*\cos(q2)*\sin(\alpha1)*\sin(\alpha2))+\cos(\alpha3)*\cos(q3)*$
$(\cos(\alpha1)*\sin(\alpha2)+\cos(\alpha2)*\cos(q2)*\sin(\alpha1))-1.0*\cos(\alpha3)*\sin(\alpha1)*\sin(q2)*\sin(q3))+$
$1.0*\cos(\alpha4)*\cos(q4)*(\sin(q3)*(\cos(\alpha1)*\sin(\alpha2)+\cos(\alpha2)*\cos(q2)*\sin(\alpha1))+\cos(q3)*$
$\sin(\alpha1)*\sin(q2)))-1.0*\cos(\alpha5)*\sin(q5)*(\cos(q4)*(\sin(\alpha3)*(\cos(\alpha1)*\cos(\alpha2)-1.0*$
$\cos(q2)*\sin(\alpha1)*\sin(\alpha2))+\cos(\alpha3)*\cos(q3)*(\cos(\alpha1)*\sin(\alpha2)+\cos(\alpha2)*\cos(q2)*$
$\sin(\alpha1))-1.0*\cos(\alpha3)*\sin(\alpha1)*\sin(q2)*\sin(q3))-\sin(q4)*(\sin(q3)*(\cos(\alpha1)*\sin(\alpha2)+$
$\cos(\alpha2)*\cos(q2)*\sin(\alpha1))+\cos(q3)*\sin(\alpha1)*\sin(q2)))$

$W_s(18,5) = -\cos(\alpha5)*\sin(q5)*(\sin(\alpha4)*(\cos(\alpha3)*(\cos(\alpha1)*\cos(\alpha2)-1.0*\cos(q2)*$
$\sin(\alpha1)*\sin(\alpha2))-1.0*\cos(q3)*\sin(\alpha3)*(\cos(\alpha1)*\sin(\alpha2)+\cos(\alpha2)*\cos(q2)*\sin(\alpha1))+$
$\sin(\alpha1)*\sin(\alpha3)*\sin(q2)*\sin(q3))+\cos(\alpha4)*\cos(q4)*(\sin(\alpha3)*(\cos(\alpha1)*\cos(\alpha2)-1.0*$

$\cos(q2) * sin(\alpha1) * sin(\alpha2)) + \cos(\alpha3) * \cos(q3) * (\cos(\alpha1) * sin(\alpha2) + \cos(\alpha2) * \cos(q2) *$
$\sin(\alpha1)) - 1.0 * \cos(\alpha3) * \sin(\alpha1) * \sin(q2) * \sin(q3)) - 1.0 * \cos(\alpha4) * \sin(q4) * (\sin(q3) * (\cos(\alpha1) *$
$\sin(\alpha2) + \cos(\alpha2) * \cos(q2) * \sin(\alpha1)) + \cos(q3) * \sin(\alpha1) * \sin(q2))) - 1.0 * \cos(\alpha5) * \cos(q5) *$
$(\sin(q4) * (\sin(\alpha3) * (\cos(\alpha1) * \cos(\alpha2) - 1.0 * \cos(q2) * \sin(\alpha1) * \sin(\alpha2)) + \cos(\alpha3) * \cos(q3) *$
$(\cos(\alpha1) * \sin(\alpha2) + \cos(\alpha2) * \cos(q2) * \sin(\alpha1)) - 1.0 * \cos(\alpha3) * \sin(\alpha1) * \sin(q2) * \sin(q3)) +$
$\cos(q4) * (\sin(q3) * (\cos(\alpha1) * \sin(\alpha2) + \cos(\alpha2) * \cos(q2) * \sin(\alpha1)) + \cos(q3) * \sin(\alpha1) * \sin(q2)))$

$W_s(19, 1) = 0$

$W_s(19, 2) = \cos(\alpha5) * (\cos(\alpha4) * (1.0 * \cos(\alpha3) * \sin(\alpha1) * \sin(\alpha2) * \sin(q2) + \cos(q2) *$
$\sin(\alpha1) * \sin(\alpha3) * \sin(q3) + 1.0 * \cos(\alpha2) * \cos(q3) * \sin(\alpha1) * \sin(\alpha3) * \sin(q2)) + \sin(\alpha4) *$
$\sin(q4) * (\cos(q2) * \cos(q3) * \sin(\alpha1) - \cos(\alpha2) * \sin(\alpha1) * \sin(q2) * \sin(q3)) + 1.0 * \cos(q4) *$
$\sin(\alpha4) * (1.0 * \cos(\alpha3) * \cos(q2) * \sin(\alpha1) * \sin(q3) - 1.0 * \sin(\alpha1) * \sin(\alpha2) * \sin(\alpha3) *$
$\sin(q2) + \cos(\alpha2) * \cos(\alpha3) * \cos(q3) * \sin(\alpha1) * \sin(q2))) + 1.0 * \cos(q5) * \sin(\alpha5) * (1.0 *$
$\cos(\alpha4) * \sin(q4) * (\cos(q2) * \cos(q3) * \sin(\alpha1) - \cos(\alpha2) * \sin(\alpha1) * \sin(q2) * \sin(q3)) -$
$\sin(\alpha4) * (1.0 * \cos(\alpha3) * \sin(\alpha1) * \sin(\alpha2) * \sin(q2) + \cos(q2) * \sin(\alpha1) * \sin(\alpha3) * \sin(q3) +$
$1.0 * \cos(\alpha2) * \cos(q3) * \sin(\alpha1) * \sin(\alpha3) * \sin(q2)) + \cos(\alpha4) * \cos(q4) * (1.0 * \cos(\alpha3) *$
$\cos(q2) * \sin(\alpha1) * \sin(q3) - 1.0 * \sin(\alpha1) * \sin(\alpha2) * \sin(\alpha3) * \sin(q2) + \cos(\alpha2) * \cos(\alpha3) *$
$\cos(q3) * \sin(\alpha1) * \sin(q2))) + \sin(\alpha5) * \sin(q5) * (\cos(q4) * (\cos(q2) * \cos(q3) * \sin(\alpha1) -$
$\cos(\alpha2) * \sin(\alpha1) * \sin(q2) * \sin(q3)) - \sin(q4) * (1.0 * \cos(\alpha3) * \cos(q2) * \sin(\alpha1) * \sin(q3) -$
$1.0 * \sin(\alpha1) * \sin(\alpha2) * \sin(\alpha3) * \sin(q2) + \cos(\alpha2) * \cos(\alpha3) * \cos(q3) * \sin(\alpha1) * \sin(q2)))$

$W_s(19, 3) = \cos(\alpha5) * (\cos(\alpha4) * (1.0 * \sin(\alpha3) * \sin(q3) * (\cos(\alpha1) * \sin(\alpha2) + \cos(\alpha2) *$
$\cos(q2) * \sin(\alpha1)) + \cos(q3) * \sin(\alpha1) * \sin(\alpha3) * \sin(q2)) + 1.0 * \cos(q4) * \sin(\alpha4) * (\cos(\alpha3) *$
$\sin(q3) * (\cos(\alpha1) * \sin(\alpha2) + \cos(\alpha2) * \cos(q2) * \sin(\alpha1)) + 1.0 * \cos(\alpha3) * \cos(q3) * \sin(\alpha1) *$
$\sin(q2)) + \sin(\alpha4) * \sin(q4) * (\cos(q3) * (\cos(\alpha1) * \sin(\alpha2) + \cos(\alpha2) * \cos(q2) * \sin(\alpha1)) -$

$\sin(\alpha1) * \sin(q2) * \sin(q3))) - \sin(\alpha5) * \sin(q5) * (\sin(q4) * (\cos(\alpha3) * \sin(q3) * (\cos(\alpha1) * \sin(\alpha2) + \cos(\alpha2) * \cos(q2) * \sin(\alpha1)) + 1.0 * \cos(\alpha3) * \cos(q3) * \sin(\alpha1) * \sin(q2)) - \cos(q4) * (\cos(q3) * (\cos(\alpha1) * \sin(\alpha2) + \cos(\alpha2) * \cos(q2) * \sin(\alpha1)) - \sin(\alpha1) * \sin(q2) * \sin(q3))) + 1.0 * \cos(q5) * \sin(\alpha5) * (\cos(\alpha4) * \cos(q4) * (\cos(\alpha3) * \sin(q3) * (\cos(\alpha1) * \sin(\alpha2) + \cos(\alpha2) * \cos(q2) * \sin(\alpha1)) + 1.0 * \cos(\alpha3) * \cos(q3) * \sin(\alpha1) * \sin(q2)) - \sin(\alpha4) * (1.0 * \sin(\alpha3) * \sin(q3) * (\cos(\alpha1) * \sin(\alpha2) + \cos(\alpha2) * \cos(q2) * \sin(\alpha1)) + \cos(q3) * \sin(\alpha1) * \sin(\alpha3) * \sin(q2)) + 1.0 * \cos(\alpha4) * \sin(q4) * (\cos(q3) * (\cos(\alpha1) * \sin(\alpha2) + \cos(\alpha2) * \cos(q2) * \sin(\alpha1)) - \sin(\alpha1) * \sin(q2) * \sin(q3)))$

$W_s(19, 4) = \cos(\alpha5) * (1.0 * \sin(\alpha4) * \sin(q4) * (\sin(\alpha3) * (\cos(\alpha1) * \cos(\alpha2) - 1.0 * \cos(q2) * \sin(\alpha1) * \sin(\alpha2)) + \cos(\alpha3) * \cos(q3) * (\cos(\alpha1) * \sin(\alpha2) + \cos(\alpha2) * \cos(q2) * \sin(\alpha1)) - 1.0 * \cos(\alpha3) * \sin(\alpha1) * \sin(q2) * \sin(q3)) + \cos(q4) * \sin(\alpha4) * (\sin(q3) * (\cos(\alpha1) * \sin(\alpha2) + \cos(\alpha2) * \cos(q2) * \sin(\alpha1)) + \cos(q3) * \sin(\alpha1) * \sin(q2))) + 1.0 * \cos(q5) * \sin(\alpha5) * (\cos(\alpha4) * \sin(q4) * (\sin(\alpha3) * (\cos(\alpha1) * \cos(\alpha2) - 1.0 * \cos(q2) * \sin(\alpha1) * \sin(\alpha2)) + \cos(\alpha3) * \cos(q3) * (\cos(\alpha1) * \sin(\alpha2) + \cos(\alpha2) * \cos(q2) * \sin(\alpha1)) - 1.0 * \cos(\alpha3) * \sin(\alpha1) * \sin(q2) * \sin(q3)) + 1.0 * \cos(\alpha4) * \cos(q4) * (\sin(q3) * (\cos(\alpha1) * \sin(\alpha2) + \cos(\alpha2) * \cos(q2) * \sin(\alpha1)) + \cos(q3) * \sin(\alpha1) * \sin(q2))) + \sin(\alpha5) * \sin(q5) * (\cos(q4) * (\sin(\alpha3) * (\cos(\alpha1) * \cos(\alpha2) - 1.0 * \cos(q2) * \sin(\alpha1) * \sin(\alpha2)) + \cos(\alpha3) * \cos(q3) * (\cos(\alpha1) * \sin(\alpha2) + \cos(\alpha2) * \cos(q2) * \sin(\alpha1)) - 1.0 * \cos(\alpha3) * \sin(\alpha1) * \sin(q2) * \sin(q3)) - \sin(q4) * (\sin(q3) * (\cos(\alpha1) * \sin(\alpha2) + \cos(\alpha2) * \cos(q2) * \sin(\alpha1)) + \cos(q3) * \sin(\alpha1) * \sin(q2)))$

$W_s(19, 5) = 1.0 * \sin(\alpha5) * \sin(q5) * (\sin(\alpha4) * (\cos(\alpha3) * (\cos(\alpha1) * \cos(\alpha2) - 1.0 * \cos(q2) * \sin(\alpha1) * \sin(\alpha2)) - 1.0 * \cos(q3) * \sin(\alpha3) * (\cos(\alpha1) * \sin(\alpha2) + \cos(\alpha2) * \cos(q2) * \sin(\alpha1)) + \sin(\alpha1) * \sin(\alpha3) * \sin(q2) * \sin(q3)) + \cos(\alpha4) * \cos(q4) * (\sin(\alpha3) * (\cos(\alpha1) * \cos(\alpha2) - 1.0 * \cos(q2) * \sin(\alpha1) * \sin(\alpha2)) + \cos(\alpha3) * \cos(q3) * (\cos(\alpha1) * \sin(\alpha2) + \cos(\alpha2) * \cos(q2) * \sin(\alpha1)) - 1.0 * \cos(\alpha3) * \sin(\alpha1) * \sin(q2) * \sin(q3)) - 1.0 * \cos(\alpha4) * \sin(q4) * (\sin(q3) * (\cos(\alpha1) *$

$\sin(\alpha 2) + \cos(\alpha 2) * \cos(q2) * \sin(\alpha 1)) + \cos(q3) * \sin(\alpha 1) * \sin(q2))) + \cos(q5) * \sin(\alpha 5) *$
$(\sin(q4) * (\sin(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2) - 1.0 * \cos(q2) * \sin(\alpha 1) * \sin(\alpha 2)) + \cos(\alpha 3) * \cos(q3) *$
$(\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q2) * \sin(\alpha 1)) - 1.0 * \cos(\alpha 3) * \sin(\alpha 1) * \sin(q2) * \sin(q3)) +$
$\cos(q4) * (\sin(q3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q2) * \sin(\alpha 1)) + \cos(q3) * \sin(\alpha 1) * \sin(q2)))$

$W_s(20, 1) = 0$

$W_s(20, 2) = d4 * (1.0 * \cos(\alpha 3) * \sin(\alpha 1) * \sin(\alpha 2) * \sin(q2) + \cos(q2) * \sin(\alpha 1) * \sin(\alpha 3) *$
$\sin(q3) + 1.0 * \cos(\alpha 2) * \cos(q3) * \sin(\alpha 1) * \sin(\alpha 3) * \sin(q2)) + d5 * (\cos(\alpha 4) * (1.0 * \cos(\alpha 3) *$
$\sin(\alpha 1) * \sin(\alpha 2) * \sin(q2) + \cos(q2) * \sin(\alpha 1) * \sin(\alpha 3) * \sin(q3) + 1.0 * \cos(\alpha 2) * \cos(q3) *$
$\sin(\alpha 1) * \sin(\alpha 3) * \sin(q2)) + \sin(\alpha 4) * \sin(q4) * (\cos(q2) * \cos(q3) * \sin(\alpha 1) - \cos(\alpha 2) * \sin(\alpha 1) *$
$\sin(q2) * \sin(q3)) + 1.0 * \cos(q4) * \sin(\alpha 4) * (1.0 * \cos(\alpha 3) * \cos(q2) * \sin(\alpha 1) * \sin(q3) - 1.0 *$
$\sin(\alpha 1) * \sin(\alpha 2) * \sin(\alpha 3) * \sin(q2) + \cos(\alpha 2) * \cos(\alpha 3) * \cos(q3) * \sin(\alpha 1) * \sin(q2))) + a2 *$
$\cos(q2) * \sin(\alpha 1) + a4 * \cos(q4) * (\cos(q2) * \cos(q3) * \sin(\alpha 1) - \cos(\alpha 2) * \sin(\alpha 1) * \sin(q2) *$
$\sin(q3)) - a5 * \sin(q5) * (1.0 * \cos(\alpha 4) * \sin(q4) * (\cos(q2) * \cos(q3) * \sin(\alpha 1) - \cos(\alpha 2) *$
$\sin(\alpha 1) * \sin(q2) * \sin(q3)) - \sin(\alpha 4) * (1.0 * \cos(\alpha 3) * \sin(\alpha 1) * \sin(\alpha 2) * \sin(q2) + \cos(q2) *$
$\sin(\alpha 1) * \sin(\alpha 3) * \sin(q3) + 1.0 * \cos(\alpha 2) * \cos(q3) * \sin(\alpha 1) * \sin(\alpha 3) * \sin(q2)) + \cos(\alpha 4) *$
$\cos(q4) * (1.0 * \cos(\alpha 3) * \cos(q2) * \sin(\alpha 1) * \sin(q3) - 1.0 * \sin(\alpha 1) * \sin(\alpha 2) * \sin(\alpha 3) * \sin(q2) +$
$\cos(\alpha 2) * \cos(\alpha 3) * \cos(q3) * \sin(\alpha 1) * \sin(q2))) + a5 * \cos(q5) * (\cos(q4) * (\cos(q2) * \cos(q3) *$
$\sin(\alpha 1) - \cos(\alpha 2) * \sin(\alpha 1) * \sin(q2) * \sin(q3)) - \sin(q4) * (1.0 * \cos(\alpha 3) * \cos(q2) * \sin(\alpha 1) *$
$\sin(q3) - 1.0 * \sin(\alpha 1) * \sin(\alpha 2) * \sin(\alpha 3) * \sin(q2) + \cos(\alpha 2) * \cos(\alpha 3) * \cos(q3) * \sin(\alpha 1) *$
$\sin(q2))) - a4 * \sin(q4) * (1.0 * \cos(\alpha 3) * \cos(q2) * \sin(\alpha 1) * \sin(q3) - 1.0 * \sin(\alpha 1) * \sin(\alpha 2) *$
$\sin(\alpha 3) * \sin(q2) + \cos(\alpha 2) * \cos(\alpha 3) * \cos(q3) * \sin(\alpha 1) * \sin(q2)) + a3 * \cos(q2) * \cos(q3) *$
$\sin(\alpha 1) + 1.0 * d3 * \sin(\alpha 1) * \sin(\alpha 2) * \sin(q2) - a3 * \cos(\alpha 2) * \sin(\alpha 1) * \sin(q2) * \sin(q3)$

$W_s(20, 3) = d4 * (1.0 * \sin(\alpha 3) * \sin(q3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q2) * \sin(\alpha 1)) +$

$\cos(q3) * \sin(\alpha1) * \sin(\alpha3) * \sin(q2)) + d5 * (\cos(\alpha4) * (1.0 * \sin(\alpha3) * \sin(q3) * (\cos(\alpha1) *$
$\sin(\alpha2) + \cos(\alpha2) * \cos(q2) * \sin(\alpha1)) + \cos(q3) * \sin(\alpha1) * \sin(\alpha3) * \sin(q2)) + 1.0 * \cos(q4) *$
$\sin(\alpha4) * (\cos(\alpha3) * \sin(q3) * (\cos(\alpha1) * \sin(\alpha2) + \cos(\alpha2) * \cos(q2) * \sin(\alpha1)) + 1.0 * \cos(\alpha3) *$
$\cos(q3) * \sin(\alpha1) * \sin(q2)) + \sin(\alpha4) * \sin(q4) * (\cos(q3) * (\cos(\alpha1) * \sin(\alpha2) + \cos(\alpha2) *$
$\cos(q2) * \sin(\alpha1)) - \sin(\alpha1) * \sin(q2) * \sin(q3))) - a4 * \sin(q4) * (\cos(\alpha3) * \sin(q3) * (\cos(\alpha1) *$
$\sin(\alpha2) + \cos(\alpha2) * \cos(q2) * \sin(\alpha1)) + 1.0 * \cos(\alpha3) * \cos(q3) * \sin(\alpha1) * \sin(q2)) + a4 *$
$\cos(q4) * (\cos(q3) * (\cos(\alpha1) * \sin(\alpha2) + \cos(\alpha2) * \cos(q2) * \sin(\alpha1)) - \sin(\alpha1) * \sin(q2) *$
$\sin(q3)) - a5 * \sin(q5) * (\cos(\alpha4) * \cos(q4) * (\cos(\alpha3) * \sin(q3) * (\cos(\alpha1) * \sin(\alpha2) + \cos(\alpha2) *$
$\cos(q2) * \sin(\alpha1)) + 1.0 * \cos(\alpha3) * \cos(q3) * \sin(\alpha1) * \sin(q2)) - \sin(\alpha4) * (1.0 * \sin(\alpha3) *$
$\sin(q3) * (\cos(\alpha1) * \sin(\alpha2) + \cos(\alpha2) * \cos(q2) * \sin(\alpha1)) + \cos(q3) * \sin(\alpha1) * \sin(\alpha3) *$
$\sin(q2)) + 1.0 * \cos(\alpha4) * \sin(q4) * (\cos(q3) * (\cos(\alpha1) * \sin(\alpha2) + \cos(\alpha2) * \cos(q2) * \sin(\alpha1)) -$
$\sin(\alpha1) * \sin(q2) * \sin(q3))) - a5 * \cos(q5) * (\sin(q4) * (\cos(\alpha3) * \sin(q3) * (\cos(\alpha1) * \sin(\alpha2) +$
$\cos(\alpha2) * \cos(q2) * \sin(\alpha1)) + 1.0 * \cos(\alpha3) * \cos(q3) * \sin(\alpha1) * \sin(q2)) - \cos(q4) * (\cos(q3) *$
$(\cos(\alpha1) * \sin(\alpha2) + \cos(\alpha2) * \cos(q2) * \sin(\alpha1)) - \sin(\alpha1) * \sin(q2) * \sin(q3))) + a3 * \cos(q3) *$
$(\cos(\alpha1) * \sin(\alpha2) + \cos(\alpha2) * \cos(q2) * \sin(\alpha1)) - a3 * \sin(\alpha1) * \sin(q2) * \sin(q3)$

$W_s(20, 4) = d5 * (1.0 * \sin(\alpha4) * \sin(q4) * (\sin(\alpha3) * (\cos(\alpha1) * \cos(\alpha2) - 1.0 * \cos(q2) *$
$\sin(\alpha1) * \sin(\alpha2)) + \cos(\alpha3) * \cos(q3) * (\cos(\alpha1) * \sin(\alpha2) + \cos(\alpha2) * \cos(q2) * \sin(\alpha1)) -$
$1.0 * \cos(\alpha3) * \sin(\alpha1) * \sin(q2) * \sin(q3)) + \cos(q4) * \sin(\alpha4) * (\sin(q3) * (\cos(\alpha1) * \sin(\alpha2) +$
$\cos(\alpha2) * \cos(q2) * \sin(\alpha1)) + \cos(q3) * \sin(\alpha1) * \sin(q2))) - a5 * \sin(q5) * (\cos(\alpha4) * \sin(q4) *$
$(\sin(\alpha3) * (\cos(\alpha1) * \cos(\alpha2) - 1.0 * \cos(q2) * \sin(\alpha1) * \sin(\alpha2)) + \cos(\alpha3) * \cos(q3) * (\cos(\alpha1) *$
$\sin(\alpha2) + \cos(\alpha2) * \cos(q2) * \sin(\alpha1)) - 1.0 * \cos(\alpha3) * \sin(\alpha1) * \sin(q2) * \sin(q3)) + 1.0 *$
$\cos(\alpha4) * \cos(q4) * (\sin(q3) * (\cos(\alpha1) * \sin(\alpha2) + \cos(\alpha2) * \cos(q2) * \sin(\alpha1)) + \cos(q3) *$
$\sin(\alpha1) * \sin(q2))) + a5 * \cos(q5) * (\cos(q4) * (\sin(\alpha3) * (\cos(\alpha1) * \cos(\alpha2) - 1.0 * \cos(q2) *$
$\sin(\alpha1) * \sin(\alpha2)) + \cos(\alpha3) * \cos(q3) * (\cos(\alpha1) * \sin(\alpha2) + \cos(\alpha2) * \cos(q2) * \sin(\alpha1)) -$

$1.0 * \cos(\alpha 3) * \sin(\alpha 1) * \sin(q2) * \sin(q3)) - \sin(q4) * (\sin(q3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) *$
$\cos(q2) * \sin(\alpha 1)) + \cos(q3) * \sin(\alpha 1) * \sin(q2))) - a4 * \sin(q4) * (\sin(q3) * (\cos(\alpha 1) * \sin(\alpha 2) +$
$\cos(\alpha 2) * \cos(q2) * \sin(\alpha 1)) + \cos(q3) * \sin(\alpha 1) * \sin(q2)) + a4 * \cos(q4) * (\sin(\alpha 3) * (\cos(\alpha 1) *$
$\cos(\alpha 2) - 1.0 * \cos(q2) * \sin(\alpha 1) * \sin(\alpha 2)) + \cos(\alpha 3) * \cos(q3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) *$
$\cos(q2) * \sin(\alpha 1)) - 1.0 * \cos(\alpha 3) * \sin(\alpha 1) * \sin(q2) * \sin(q3))$

$W_s(20, 5) = a5 * \cos(q5) * (\sin(\alpha 4) * (\cos(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2) - 1.0 * \cos(q2) * \sin(\alpha 1) *$
$\sin(\alpha 2)) - 1.0 * \cos(q3) * \sin(\alpha 3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q2) * \sin(\alpha 1)) + \sin(\alpha 1) *$
$\sin(\alpha 3) * \sin(q2) * \sin(q3)) + \cos(\alpha 4) * \cos(q4) * (\sin(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2) - 1.0 * \cos(q2) *$
$\sin(\alpha 1) * \sin(\alpha 2)) + \cos(\alpha 3) * \cos(q3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q2) * \sin(\alpha 1)) -$
$1.0 * \cos(\alpha 3) * \sin(\alpha 1) * \sin(q2) * \sin(q3)) - 1.0 * \cos(\alpha 4) * \sin(q4) * (\sin(q3) * (\cos(\alpha 1) *$
$\sin(\alpha 2) + \cos(\alpha 2) * \cos(q2) * \sin(\alpha 1)) + \cos(q3) * \sin(\alpha 1) * \sin(q2))) - a5 * \sin(q5) * (\sin(q4) *$
$(\sin(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2) - 1.0 * \cos(q2) * \sin(\alpha 1) * \sin(\alpha 2)) + \cos(\alpha 3) * \cos(q3) * (\cos(\alpha 1) *$
$\sin(\alpha 2) + \cos(\alpha 2) * \cos(q2) * \sin(\alpha 1)) - 1.0 * \cos(\alpha 3) * \sin(\alpha 1) * \sin(q2) * \sin(q3)) + \cos(q4) *$
$(\sin(q3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q2) * \sin(\alpha 1)) + \cos(q3) * \sin(\alpha 1) * \sin(q2)))$