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ОЦЕНИВАНИЕ ПАРАМЕТРОВ

РОБОТА-МАНИПУЛЯТОРА КИКА YOUBOT1)

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)

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$W_s(7,3) = 0$$

$$W_s(7,4) = 0$$

$$W_s(7,5) = 0$$

$$W_s(8,1) = 0$$

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

$$W_s(8,3) = 0$$

$$W_s(8,4) = 0$$

$$W_s(8,5) = 0$$

$$W_s(9,1) = 0$$

$$W_s(9,2) = 0$$

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

$$W_s(9,4) = 0$$

$$W_s(9,5) = 0$$

$$W_s(10,1) = 0$$

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

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

$$W_s(10,4) = 0$$

$$W_s(10,5) = 0$$

$$W_s(11,1) = 0$$

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

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

$$W_s(11,4) = 0$$

$$W_s(11,5) = 0$$

$$W_s(12,1) = 0$$

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

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

$$W_s(12,4) = 0$$

$$W_s(12,5) = 0$$

$$W_s(13,1) = 0$$

$$W_s(13,2) = 0$$

 $W_{s}(13,3) = d4*(1.0*\sin(\alpha 3)*\sin(q 3)*(\cos(\alpha 1)*\sin(\alpha 2) + \cos(\alpha 2)*\cos(q 2)*\sin(\alpha 1)) + \cos(q 3)*\sin(\alpha 1)*\sin(\alpha 3)*\sin(\alpha 3)*\sin(q 2)) - \sin(q 4)*(\cos(\alpha 3)*\sin(q 3)*(\cos(\alpha 1)*\sin(\alpha 2) + \cos(\alpha 2)*\cos(q 2)*\sin(\alpha 1)) + 1.0*\cos(\alpha 3)*\cos(q 3)*\sin(\alpha 1)*\sin(q 2) + \cos(q 4)*(\cos(q 3)*(\cos(\alpha 1)*\sin(\alpha 2) + \cos(\alpha 2)*\cos(q 2)*\sin(\alpha 1)) - \sin(\alpha 1)*\sin(q 2)*\sin(q 3)) - a4*\sin(q 4)*(\cos(\alpha 3)*\sin(q 3)*(\cos(\alpha 1)*\sin(\alpha 2) + \cos(\alpha 2)*\cos(q 2)*\sin(\alpha 1)) + 1.0*\cos(\alpha 3)*\cos(q 3)*\sin(\alpha 1)*\sin(q 2) + a4*\cos(q 4)*(\cos(q 3)*(\cos(\alpha 1)*\sin(\alpha 2) + \cos(\alpha 2)*\cos(q 2)*\sin(\alpha 1)) - \sin(\alpha 1)*\sin(q 2)*\sin(q 3)) + a3*\cos(q 3)*(\cos(\alpha 1)*\sin(\alpha 2) + \cos(\alpha 2)*\cos(q 2)*\sin(\alpha 1)) - a3*\sin(\alpha 1)*\sin(q 2)*\sin(q 3)$

 $W_{s}(13,4) = \cos(q4) * (\sin(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2) - 1.0 * \cos(q2) * \sin(\alpha 1) * \sin(\alpha 2)) + \cos(\alpha 3) * \cos(q3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) - 1.0 * \cos(\alpha 3) * \sin(\alpha 1) * \sin(q 2) * \sin(q 3)) - \sin(q 4) * (\sin(q 3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) + \cos(q 3) * \sin(\alpha 1) * \sin(q 2)) - a 4 * \sin(q 4) * (\sin(q 3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) + \cos(q 3) * \sin(\alpha 1) * \sin(q 2)) + a 4 * \cos(q 4) * (\sin(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2) + \cos(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1) * \sin(\alpha 2)) + \cos(\alpha 3) * \cos(q 3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) - 1.0 * \cos(\alpha 3) * \sin(\alpha 1) * \sin(q 2) * \sin(q 3))$

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

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

 $W_{s}(14,2) = \sin(\alpha 4) * (1.0 * \cos(\alpha 3) * \sin(\alpha 1) * \sin(\alpha 2) * \sin(q 2) + \cos(q 2) * \sin(\alpha 1) * \sin(\alpha 3) * \sin(q 3) + 1.0 * \cos(\alpha 2) * \cos(q 3) * \sin(\alpha 1) * \sin(\alpha 3) * \sin(q 2)) + d 4 * (1.0 * \cos(\alpha 3) * \sin(\alpha 1) * \sin(\alpha 2) * \sin(q 2) + \cos(q 2) * \sin(\alpha 1) * \sin(\alpha 3) * \sin(q 3) + 1.0 * \cos(\alpha 2) * \cos(q 3) * \sin(\alpha 1) * \sin(\alpha 3) * \sin(q 2)) - 1.0 * \cos(\alpha 4) * \sin(q 4) * (\cos(q 2) * \cos(q 3) * \sin(\alpha 1) - \cos(\alpha 2) * \sin(\alpha 1) * \sin(q 2) * \sin(q 3)) - \cos(\alpha 4) * \cos(q 4) * (1.0 * \cos(\alpha 3) * \cos(q 2) * \sin(\alpha 1) * \sin(q 3) - 1.0 * \sin(\alpha 1) * \sin(\alpha 2) * \sin(\alpha 3) * \sin(q 2) + \cos(\alpha 2) * \cos(\alpha 3) * \cos(q 3) * \sin(\alpha 1) * \sin(q 2) + a 2 * \cos(q 2) * \sin(\alpha 1) + a 4 * \cos(q 4) * (\cos(q 2) * \cos(\alpha 3) * \sin(\alpha 1) - \cos(\alpha 2) * \sin(\alpha 1) * \sin(q 2) * \sin(\alpha 3) * \sin(q 3) + a 4 * \sin(q 4) * (1.0 * \cos(\alpha 3) * \cos(q 2) * \sin(\alpha 1) * \sin(q 3) - 1.0 * \sin(\alpha 1) * \sin(\alpha 2) * \sin(\alpha 3) * \sin(q 2) + \cos(\alpha 2) * \cos(\alpha 3) * \cos(q 2) * \sin(\alpha 1) * \sin(q 2) + a 3 * \cos(q 2) * \cos(q 3) * \sin(\alpha 1) + 1.0 * d 3 * \sin(\alpha 1) * \sin(\alpha 2) * \sin(\alpha 2) - a 3 * \cos(\alpha 2) * \sin(\alpha 1) * \sin(q 2) * \sin(\alpha 3) * \sin(\alpha 1) * \sin(\alpha 3) * \cos(\alpha 3) * \cos($

$$\begin{split} &\sin(q2)) + a4 * \cos(q4) * (\cos(q3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) - \sin(\alpha 1) * \\ &\sin(q2) * \sin(q3)) - \cos(\alpha 4) * \cos(q 4) * (\cos(\alpha 3) * \sin(q 3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \\ &\cos(q 2) * \sin(\alpha 1)) + 1.0 * \cos(\alpha 3) * \cos(q 3) * \sin(\alpha 1) * \sin(q 2)) + a 3 * \cos(q 3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) - 1.0 * \cos(\alpha 4) * \sin(q 4) * (\cos(q 3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) - \sin(\alpha 1) * \sin(q 2) * \sin(q 3)) - a 3 * \sin(\alpha 1) * \sin(q 2) * \sin(q 3) \\ &W_s(14,4) = a 4 * \cos(q 4) * (\sin(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2) - 1.0 * \cos(q 2) * \sin(\alpha 1) * \sin(\alpha 2)) + \cos(\alpha 3) * \cos(q 3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) - 1.0 * \cos(\alpha 3) * \sin(\alpha 1) * \sin(q 2) * \sin(q 3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) + \cos(q 3) * \sin(\alpha 1) * \sin(q 2) * \sin(\alpha 1) * \sin(q 2) * \cos(q 2) * \sin(\alpha 1)) + \cos(q 3) * \sin(\alpha 1) * \sin(q 2) - 1.0 * \cos(\alpha 4) * \sin(q 2) - \cos(\alpha 4) * \sin(q 4) * (\sin(\alpha 3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) + \cos(q 3) * \sin(\alpha 1) * \sin(q 2) - \cos(\alpha 4) * \sin(q 4) * (\sin(\alpha 3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) + \cos(q 3) * \sin(\alpha 1) * \sin(q 2) - \cos(\alpha 4) * \sin(q 4) * (\sin(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) + \cos(q 3) * \sin(\alpha 1) * \sin(q 2) + \cos(\alpha 3) * \cos(q 3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) + \cos(q 3) * \sin(\alpha 1) * \sin(q 2) + \cos(\alpha 3) * \cos(q 3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) + \cos(\alpha 3) * \sin(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 3) * \cos(\alpha$$

$$W_s(14,5) = 0$$

$$W_{s}(15,1)=0$$

 $W_{s}(15,2) = \cos(\alpha 4) * (1.0 * \cos(\alpha 3) * \sin(\alpha 1) * \sin(\alpha 2) * \sin(q 2) + \cos(q 2) * \sin(\alpha 1) * \sin(\alpha 3) * \sin(q 3) + 1.0 * \cos(\alpha 2) * \cos(q 3) * \sin(\alpha 1) * \sin(\alpha 3) * \sin(q 2)) + d 4 * (1.0 * \cos(\alpha 3) * \sin(\alpha 1) * \sin(\alpha 2) * \sin(q 2) + \cos(q 2) * \sin(\alpha 1) * \sin(\alpha 3) * \sin(q 3) + 1.0 * \cos(\alpha 2) * \cos(q 3) * \sin(\alpha 1) * \sin(\alpha 3) * \sin(q 2)) + \sin(\alpha 4) * \sin(q 4) * (\cos(q 2) * \cos(q 3) * \sin(\alpha 1) - \cos(\alpha 2) * \sin(\alpha 1) * \sin(q 2) * \sin(q 3)) + 1.0 * \cos(q 4) * \sin(\alpha 4) * (1.0 * \cos(\alpha 3) * \cos(q 2) * \sin(\alpha 1) * \sin(q 3) - 1.0 * \sin(\alpha 1) * \sin(\alpha 2) * \sin(\alpha 3) * \sin(\alpha 3) * \sin(\alpha 2) * \cos(q 3) * \sin(\alpha 1) - \cos(\alpha 2) * \sin(\alpha 1) * \sin(q 2) * \sin(\alpha 3) + a 4 * \cos(q 4) * (\cos(q 2) * \cos(q 3) * \sin(\alpha 1) - \cos(\alpha 2) * \sin(\alpha 1) * \sin(q 2) * \sin(q 3) - a 4 * \sin(q 4) * (1.0 * \cos(\alpha 3) * \cos(q 2) * \sin(\alpha 1) * \sin(q 3) - 1.0 * \sin(\alpha 2) * \sin(\alpha 3) * \sin(q 2) + \cos(\alpha 3) * \cos(q 3) * \sin(\alpha 1) * \sin(q 3) - 1.0 * \sin(\alpha 1) * \sin(\alpha 2) * \sin(\alpha 3) * \sin(q 2) + \cos(\alpha 2) * \cos(\alpha 3) * \cos(q 3) * \sin(\alpha 1) * \sin(q 2) + a 3 * \cos(q 2) * \cos(q 3) * \sin(\alpha 3) * \sin(q 2) + \cos(\alpha 2) * \cos(q 3) * \sin(\alpha 3) * \sin(q 2) + \cos(\alpha 3) * \cos(q 3) * \sin(\alpha 3) * \sin(q 2) + \cos(\alpha 3) * \cos(q 3) * \sin(\alpha 3) * \sin(\alpha 3) * \cos(q 3) * \cos(\alpha 3) * \cos($

$$\begin{split} &\sin(\alpha 1) + 1.0*d3*\sin(\alpha 1)*\sin(\alpha 2)*\sin(\alpha 2)*\sin(\alpha 2) - a3*\cos(\alpha 2)*\sin(\alpha 1)*\sin(\alpha 2)*\sin(\alpha 3) \\ &W_s(15,3) = d4*(1.0*\sin(\alpha 3)*\sin(\alpha 3)*(\cos(\alpha 1)*\sin(\alpha 2) + \cos(\alpha 2)*\cos(\alpha 2)*\sin(\alpha 1)) + \cos(\alpha 3)*\sin(\alpha 1)*\sin(\alpha 3)*\sin(\alpha 3)*\cos(\alpha 3)*\sin(\alpha 3)*\sin(\alpha 3)*\cos(\alpha 3)*\sin(\alpha 3)*\cos(\alpha 3)*\sin(\alpha 3)*\sin(\alpha 3)*\cos(\alpha 3)*\sin(\alpha 3)*\sin(\alpha 3)*\cos(\alpha 3)*\sin(\alpha 3)*\cos(\alpha 3)*\sin(\alpha 3)*\sin(\alpha 3)*\cos(\alpha 3)*\sin(\alpha 3)*\cos(\alpha 3)*\sin(\alpha 3)*\cos(\alpha 3)*\sin(\alpha 3)*\sin(\alpha 3)*\cos(\alpha 3)*\sin(\alpha 3)*\cos(\alpha 3)*\sin(\alpha 3)*\cos(\alpha 3)*\sin(\alpha 3)*\cos(\alpha 3)*\sin(\alpha 3)*\cos(\alpha 3)*\cos(\alpha$$

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

$$W_{s}(16,2)=0$$

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

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

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

$$W_s(17,1) = 0$$

 $W_s(17,2) = \cos(q5) * (\cos(q4) * (\cos(q2) * \cos(q3) * \sin(\alpha 1) - \cos(\alpha 2) * \sin(\alpha 1) * \sin(q2) *$ $\sin(q3)$) $-\sin(q4)*(1.0*\cos(\alpha 3)*\cos(q2)*\sin(\alpha 1)*\sin(q3) - 1.0*\sin(\alpha 1)*\sin(\alpha 2)*\sin(\alpha 3)*$ $\sin(q2) + \cos(\alpha 2) * \cos(\alpha 3) * \cos(q3) * \sin(\alpha 1) * \sin(q2)) - \sin(q5) * (1.0 * \cos(\alpha 4) * \sin(q4) *$ $(\cos(q2)*\cos(q3)*\sin(\alpha 1) - \cos(\alpha 2)*\sin(\alpha 1)*\sin(q2)*\sin(q3)) - \sin(\alpha 4)*(1.0*\cos(\alpha 3)*\sin(\alpha 1) + \cos(\alpha 1)*\sin(\alpha 1) + \sin(\alpha 1) + \cos(\alpha 1$ $\sin(\alpha 1) * \sin(\alpha 2) * \sin(\alpha 2) + \cos(\alpha 2) * \sin(\alpha 1) * \sin(\alpha 3) * \sin(\alpha 3) + 1.0 * \cos(\alpha 2) * \cos(\alpha 3) *$ $\sin(\alpha 1) * \sin(\alpha 3) * \sin(\alpha 2) + \cos(\alpha 4) * \cos(\alpha 4) * (1.0 * \cos(\alpha 3) * \cos(\alpha 2) * \sin(\alpha 1) * \sin(\alpha 3) - \cos(\alpha 4) * \sin(\alpha 3) * \sin(\alpha 4) * \cos(\alpha 4) * \cos(\alpha$ $1.0 * \sin(\alpha 1) * \sin(\alpha 2) * \sin(\alpha 3) * \sin(q 2) + \cos(\alpha 2) * \cos(\alpha 3) * \cos(q 3) * \sin(\alpha 1) * \sin(q 2)))$ $W_s(17,3) = -\cos(q5) * (\sin(q4) * (\cos(\alpha 3) * \sin(q3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) *$ $\cos(q2) * \sin(\alpha 1)) + 1.0 * \cos(\alpha 3) * \cos(q3) * \sin(\alpha 1) * \sin(q2)) - \cos(q4) * (\cos(q3) * (\cos(\alpha 1) * \cos(\alpha 1$ $\sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) - \sin(\alpha 1) * \sin(q 2) * \sin(q 3))) - \sin(q 5) * (\cos(\alpha 4) * \sin(q 3)) + \sin(q 3))$ $\cos(q4) * (\cos(\alpha 3) * \sin(q3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q2) * \sin(\alpha 1)) + 1.0 * \cos(\alpha 3) *$ $\cos(q3) * \sin(\alpha 1) * \sin(q2)) - \sin(\alpha 4) * (1.0 * \sin(\alpha 3) * \sin(q3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) *$ $\cos(q2) * \sin(\alpha 1)) + \cos(q3) * \sin(\alpha 1) * \sin(\alpha 3) * \sin(q2)) + 1.0 * \cos(\alpha 4) * \sin(q4) * (\cos(q3) * \sin(\alpha 1)) + \cos(\alpha 1) * \sin(\alpha 1) * \cos(\alpha 1$ $(\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) - \sin(\alpha 1) * \sin(q 2) * \sin(q 3)))$ $W_s(17,4) = \cos(q5) * (\cos(q4) * (\sin(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2) - 1.0 * \cos(q 2) * \sin(\alpha 1) *$ $\sin(\alpha 2) + \cos(\alpha 3) * \cos(\alpha 3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(\alpha 2) * \sin(\alpha 1)) - 1.0 * \cos(\alpha 3) *$ $\sin(\alpha 1) * \sin(q 2) * \sin(q 3)) - \sin(q 4) * (\sin(q 3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) *$ $\sin(\alpha 1) + \cos(q 3) * \sin(\alpha 1) * \sin(q 2)) - \sin(q 5) * (\cos(\alpha 4) * \sin(q 4) * (\sin(\alpha 3) * (\cos(\alpha 1) * \sin(q 4) * \sin(q 4))))$ $\cos(\alpha 2) - 1.0 * \cos(q 2) * \sin(\alpha 1) * \sin(\alpha 2)) + \cos(\alpha 3) * \cos(q 3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(\alpha 3) * \cos($ $\cos(q2) * \sin(\alpha 1) - 1.0 * \cos(\alpha 3) * \sin(\alpha 1) * \sin(q2) * \sin(q3) + 1.0 * \cos(\alpha 4) * \cos(q4) *$ $(\sin(q3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) + \cos(q 3) * \sin(\alpha 1) * \sin(q 2)))$ $W_{s}(17,5) = \cos(q5) * (\sin(\alpha 4) * (\cos(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2) - 1.0 * \cos(q 2) * \sin(\alpha 1) *$ $\sin(\alpha 2)) - 1.0 * \cos(q 3) * \sin(\alpha 3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) + \sin(\alpha 1) *$ $\sin(\alpha 3) * \sin(q 2) * \sin(q 3)) + \cos(\alpha 4) * \cos(q 4) * (\sin(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2) - 1.0 * \cos(q 2) *$ $\sin(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 3) * \cos(q 3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) 1.0 * \cos(\alpha 3) * \sin(\alpha 1) * \sin(\alpha 2) * \sin(\alpha 3) - 1.0 * \cos(\alpha 4) * \sin(\alpha 4) * (\sin(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 4) * \sin(\alpha 4) * \cos(\alpha 4) * \sin(\alpha 4) * \cos(\alpha 4$ $\sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) + \cos(q 3) * \sin(\alpha 1) * \sin(q 2))) - \sin(q 5) * (\sin(q 4) * \sin(q 4)) + \cos(q 3) * \sin(q 4)) + \cos(q 4) * \cos(q 4) + \cos(q 4)) + \cos(q 4) + \cos(q 4) + \cos(q 4) + \cos(q 4)) + \cos(q 4) + \cos($ $(\sin(\alpha 3)*(\cos(\alpha 1)*\cos(\alpha 2)-1.0*\cos(q 2)*\sin(\alpha 1)*\sin(\alpha 2))+\cos(\alpha 3)*\cos(q 3)*(\cos(\alpha 1)*\cos(q 3)*\cos(q 3)$ $\sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) - 1.0 * \cos(\alpha 3) * \sin(\alpha 1) * \sin(q 2) * \sin(q 3)) + \cos(q 4) *$ $(\sin(q3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) + \cos(q 3) * \sin(\alpha 1) * \sin(q 2)))$ $W_s(18,1) = 0$ $W_s(18,2) = \sin(\alpha 5) * (\cos(\alpha 4) * (1.0 * \cos(\alpha 3) * \sin(\alpha 1) * \sin(\alpha 2) * \sin(\alpha 2) + \cos(\alpha 2) *$ $\sin(\alpha 1) * \sin(\alpha 3) * \sin(\alpha 3) + 1.0 * \cos(\alpha 2) * \cos(\alpha 3) * \sin(\alpha 1) * \sin(\alpha 3) * \sin(\alpha 2)) + \sin(\alpha 4) *$ $\sin(q4) * (\cos(q2) * \cos(q3) * \sin(\alpha 1) - \cos(\alpha 2) * \sin(\alpha 1) * \sin(q2) * \sin(q3)) + 1.0 * \cos(q4) *$ $\sin(\alpha 4) * (1.0 * \cos(\alpha 3) * \cos(q 2) * \sin(\alpha 1) * \sin(q 3) - 1.0 * \sin(\alpha 1) * \sin(\alpha 2) * \sin(\alpha 3) *$ $\sin(q2) + \cos(\alpha 2) * \cos(\alpha 3) * \cos(q3) * \sin(\alpha 1) * \sin(q2)) - 1.0 * \cos(\alpha 5) * \sin(q5) * (\cos(q4) * \cos(q5) * \cos(q5) * \sin(q5) * \cos(q5) * \cos(q5) * \sin(q5) * \cos(q5) * \sin(q5) * \cos(q5) *$ $(\cos(q2)*\cos(q3)*\sin(\alpha 1) - \cos(\alpha 2)*\sin(\alpha 1)*\sin(q2)*\sin(q3)) - \sin(q4)*(1.0*\cos(\alpha 3)*$ $\cos(q^2) * \sin(\alpha^2) * \sin(q^3) - 1.0 * \sin(\alpha^2) * \sin(\alpha^2) * \sin(\alpha^3) * \sin(q^2) + \cos(\alpha^2) * \cos(\alpha^3) *$ $\cos(q3) * \sin(\alpha 1) * \sin(q2))) - \cos(\alpha 5) * \cos(q5) * (1.0 * \cos(\alpha 4) * \sin(q4) * (\cos(q2) * \cos(q3) * \sin(q4) * \cos(q3) * \cos(q3) * \sin(q4) * \cos(q3) *$ $\sin(\alpha 1) - \cos(\alpha 2) * \sin(\alpha 1) * \sin(\alpha 2) * \sin(\alpha 3)) - \sin(\alpha 4) * (1.0 * \cos(\alpha 3) * \sin(\alpha 1) * \sin(\alpha 2) *$ $\sin(q^2) + \cos(q^2) * \sin(\alpha^2) * \sin(\alpha^3) * \sin(q^3) + 1.0 * \cos(\alpha^2) * \cos(q^3) * \sin(\alpha^2) * \sin(\alpha^3) * \cos(\alpha^3) * \cos(\alpha^$ $\sin(q2)$) + $\cos(\alpha 4) * \cos(q4) * (1.0 * \cos(\alpha 3) * \cos(q2) * \sin(\alpha 1) * \sin(q3) - 1.0 * \sin(\alpha 1) *$ $\sin(\alpha 2) * \sin(\alpha 3) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(\alpha 3) * \cos(\alpha 3) * \sin(\alpha 1) * \sin(\alpha 2)))$ $W_s(18,3) = \sin(\alpha 5) * (\cos(\alpha 4) * (1.0 * \sin(\alpha 3) * \sin(q 3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) *$ $\cos(q2) * \sin(\alpha 1) + \cos(q3) * \sin(\alpha 1) * \sin(\alpha 3) * \sin(q2) + 1.0 * \cos(q4) * \sin(\alpha 4) * (\cos(\alpha 3) * \sin(\alpha 1) + \cos(\alpha 1) * \sin(\alpha 1) * \sin(\alpha 1) * \sin(\alpha 2) + 1.0 * \cos(\alpha 1) * \sin(\alpha 1) * \cos(\alpha 1) * \sin(\alpha 1) * \cos(\alpha 1) * \cos$

 $\sin(q3)*(\cos(\alpha 1)*\sin(\alpha 2)+\cos(\alpha 2)*\cos(q2)*\sin(\alpha 1))+1.0*\cos(\alpha 3)*\cos(q3)*\sin(\alpha 1)*$ $\sin(q2) + \sin(\alpha 4) * \sin(q4) * (\cos(q3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) - \cos(\alpha 2) * \sin(\alpha 2) + \sin(\alpha 2) * \cos(\alpha 2) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(\alpha 2) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(\alpha 2) * \sin(\alpha 2) + \cos(\alpha 2) * \sin(\alpha 2) + \cos(\alpha 2) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(\alpha 2) * \sin(\alpha 2) + \cos(\alpha 2) * \cos$ $\sin(\alpha 1) * \sin(q 2) * \sin(q 3)) + 1.0 * \cos(\alpha 5) * \sin(q 5) * (\sin(q 4) * (\cos(\alpha 3) * \sin(q 3) * (\cos(\alpha 1) * \cos(\alpha 1) * (\cos(\alpha 1) * \cos(\alpha 1) * (\cos(\alpha 1) * (\cos(\alpha 1) * \cos(\alpha 1) * (\cos(\alpha 1) * (oo(\alpha 1) * ($ $\sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) + 1.0 * \cos(\alpha 3) * \cos(q 3) * \sin(\alpha 1) * \sin(q 2)) - \cos(q 4) *$ $(\cos(q3)*(\cos(\alpha 1)*\sin(\alpha 2)+\cos(\alpha 2)*\cos(q2)*\sin(\alpha 1))-\sin(\alpha 1)*\sin(q2)*\sin(q3)))$ $\cos(\alpha 5) * \cos(q 5) * (\cos(\alpha 4) * \cos(q 4) * (\cos(\alpha 3) * \sin(q 3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \cos(\alpha 3) * \cos(\alpha 4) * \cos(\alpha 4)$ $\sin(\alpha 1) + 1.0 * \cos(\alpha 3) * \cos(\alpha 3) * \sin(\alpha 1) * \sin(\alpha 2) - \sin(\alpha 4) * (1.0 * \sin(\alpha 3) * \sin(\alpha 3) * (\cos(\alpha 1) * \sin(\alpha 3) * \cos(\alpha 3) * \cos(\alpha 3) * \cos(\alpha 3) * \cos(\alpha 3) * \sin(\alpha 3) * \cos(\alpha 3$ $\sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) + \cos(q 3) * \sin(\alpha 1) * \sin(\alpha 3) * \sin(q 2)) + 1.0 * \cos(\alpha 4) *$ $\sin(q4)*(\cos(q3)*(\cos(\alpha 1)*\sin(\alpha 2)+\cos(\alpha 2)*\cos(q2)*\sin(\alpha 1))-\sin(\alpha 1)*\sin(q2)*\sin(q3)))$ $W_s(18,4) = \sin(\alpha 5) * (1.0 * \sin(\alpha 4) * \sin(q 4) * (\sin(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2) - 1.0 * \cos(q 2) * (\cos(\alpha 1) * \cos(\alpha 2) + \cos(\alpha 2) * (\cos(\alpha 1) * (\cos(\alpha 1) * \cos(\alpha 2) * (\cos(\alpha 1) * (o) * (o$ $\sin(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 3) * \cos(q 3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) 1.0 * \cos(\alpha 3) * \sin(\alpha 1) * \sin(\alpha 2) * \sin(\alpha 3)) + \cos(\alpha 4) * \sin(\alpha 4) * (\sin(\alpha 3)) * (\cos(\alpha 1)) * \sin(\alpha 2) + \cos(\alpha 3) * \sin(\alpha 3) * \cos(\alpha 3) * \sin(\alpha 3) * \cos(\alpha 3) * \sin(\alpha 3) * \cos(\alpha 3) *$ $\cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) + \cos(q 3) * \sin(\alpha 1) * \sin(q 2))) - \cos(\alpha 5) * \cos(q 5) * (\cos(\alpha 4) * \cos(q 5)) + \cos(q 5) * \cos(q 5$ $\sin(q4) * (\sin(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2) - 1.0 * \cos(q2) * \sin(\alpha 1) * \sin(\alpha 2)) + \cos(\alpha 3) * \cos(q3) *$ $(\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) - 1.0 * \cos(\alpha 3) * \sin(\alpha 1) * \sin(q 2) * \sin(q 3)) +$ $1.0 * \cos(\alpha 4) * \cos(q 4) * (\sin(q 3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) + \cos(q 3) *$ $\sin(\alpha 1) * \sin(q 2)) - 1.0 * \cos(\alpha 5) * \sin(q 5) * (\cos(q 4) * (\sin(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2) - 1.0 *$ $\cos(q^2) * \sin(\alpha^2) * \sin(\alpha^2) + \cos(\alpha^2) * \cos(q^3) * (\cos(\alpha^2) * \sin(\alpha^2) + \cos(\alpha^2) * \cos(q^2) * \sin(\alpha^2) + \cos(\alpha^2) * \cos(\alpha^2) *$ $\sin(\alpha 1) - 1.0 * \cos(\alpha 3) * \sin(\alpha 1) * \sin(\alpha 2) * \sin(\alpha 3) - \sin(\alpha 4) * (\sin(\alpha 3) * (\cos(\alpha 1) * \sin(\alpha 2) + \sin(\alpha 3)) + \sin(\alpha 3) * \cos(\alpha 3) * \sin(\alpha 3) * \cos(\alpha 3) * \cos$ $\cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) + \cos(q 3) * \sin(\alpha 1) * \sin(q 2)))$ $W_s(18,5) = -\cos(\alpha 5) * \sin(q 5) * (\sin(\alpha 4) * (\cos(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2) - 1.0 * \cos(q 2) *$ $\sin(\alpha 1) * \sin(\alpha 2) - 1.0 * \cos(q 3) * \sin(\alpha 3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) +$ $\sin(\alpha 1) * \sin(\alpha 3) * \sin(q 2) * \sin(q 3)) + \cos(\alpha 4) * \cos(q 4) * (\sin(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2) - 1.0 *)$ $\cos(q^2) * \sin(\alpha^2) * \sin(\alpha^2) + \cos(\alpha^3) * \cos(q^3) * (\cos(\alpha^2) * \sin(\alpha^2) + \cos(\alpha^2) * \cos(q^2) * \sin(\alpha^2) + \cos(\alpha^2) * \cos(\alpha^2) * \sin(\alpha^2) + \cos(\alpha^2) * \cos(\alpha^2) *$ $\sin(\alpha 1) - 1.0 * \cos(\alpha 3) * \sin(\alpha 1) * \sin(\alpha 2) * \sin(\alpha 3) - 1.0 * \cos(\alpha 4) * \sin(\alpha 4) * (\sin(\alpha 3) * (\cos(\alpha 1) * \sin(\alpha 3) * \sin(\alpha 4) * \sin(\alpha 3) * (\cos(\alpha 4) * \sin(\alpha 4) * \sin(\alpha 4) * (\sin(\alpha 4) * (\sin(\alpha 4) * \sin(\alpha 4) * (\sin(\alpha 4) * (\cos(\alpha 4) * (oo(\alpha 4) * ($ $\sin(\alpha 2) + \cos(\alpha 2) * \cos(\alpha 2) * \sin(\alpha 1)) + \cos(\alpha 3) * \sin(\alpha 1) * \sin(\alpha 2)) - 1.0 * \cos(\alpha 5) * \cos(\alpha 5) * \cos(\alpha 5) * \sin(\alpha 1) + \cos(\alpha 2) * \cos(\alpha 5) * \cos($ $(\sin(q4)*(\sin(\alpha 3)*(\cos(\alpha 1)*\cos(\alpha 2)-1.0*\cos(q2)*\sin(\alpha 1)*\sin(\alpha 2))+\cos(\alpha 3)*\cos(q3)*$ $(\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) - 1.0 * \cos(\alpha 3) * \sin(\alpha 1) * \sin(q 2) * \sin(q 3)) +$ $\cos(q4)*(\sin(q3)*(\cos(\alpha1)*\sin(\alpha2)+\cos(\alpha2)*\cos(q2)*\sin(\alpha1))+\cos(q3)*\sin(\alpha1)*\sin(q2)))$ $W_s(19,1) = 0$ $W_s(19,2) = \cos(\alpha 5) * (\cos(\alpha 4) * (1.0 * \cos(\alpha 3) * \sin(\alpha 1) * \sin(\alpha 2) * \sin(\alpha 2) * \cos(\alpha 2) *$ $\sin(\alpha 1) * \sin(\alpha 3) * \sin(q 3) + 1.0 * \cos(\alpha 2) * \cos(q 3) * \sin(\alpha 1) * \sin(\alpha 3) * \sin(q 2)) + \sin(\alpha 4) *$ $\sin(q4) * (\cos(q2) * \cos(q3) * \sin(\alpha 1) - \cos(\alpha 2) * \sin(\alpha 1) * \sin(q2) * \sin(q3)) + 1.0 * \cos(q4) *$ $\sin(\alpha 4) * (1.0 * \cos(\alpha 3) * \cos(q 2) * \sin(\alpha 1) * \sin(q 3) - 1.0 * \sin(\alpha 1) * \sin(\alpha 2) * \sin(\alpha 3) *$ $\sin(q^2) + \cos(\alpha^2) * \cos(\alpha^3) * \cos(q^3) * \sin(\alpha^4) * \sin(q^2) + 1.0 * \cos(q^5) * \sin(\alpha^5) * (1.0 * \cos(q^5) * \sin(\alpha^4) * \cos(\alpha^4) * \cos(\alpha^4) * \cos(\alpha^4) * \sin(\alpha^4) * \sin(\alpha^4)$ $\cos(\alpha 4) * \sin(q 4) * (\cos(q 2) * \cos(q 3) * \sin(\alpha 1) - \cos(\alpha 2) * \sin(\alpha 1) * \sin(q 2) * \sin(q 3)) \sin(\alpha 4) * (1.0 * \cos(\alpha 3) * \sin(\alpha 1) * \sin(\alpha 2) * \sin(q 2) + \cos(q 2) * \sin(\alpha 1) * \sin(\alpha 3) * \sin(q 3) + \sin(\alpha 1) * \cos(\alpha 1) * \cos(\alpha$ $1.0 * \cos(\alpha 2) * \cos(q 3) * \sin(\alpha 1) * \sin(\alpha 3) * \sin(q 2)) + \cos(\alpha 4) * \cos(q 4) * (1.0 * \cos(\alpha 3) *$ $\cos(q^2) * \sin(\alpha^2) * \sin(q^3) - 1.0 * \sin(\alpha^2) * \sin(\alpha^2) * \sin(\alpha^3) * \sin(q^2) + \cos(\alpha^2) * \cos(\alpha^3) *$ $\cos(q3) * \sin(\alpha 1) * \sin(q2)) + \sin(\alpha 5) * \sin(q5) * (\cos(q4) * (\cos(q2) * \cos(q3) * \sin(\alpha 1) - \cos(q3) * \sin(\alpha 1)) + \sin(\alpha 1) * \cos(\alpha 1) * \cos(\alpha$ $\cos(\alpha 2) * \sin(\alpha 1) * \sin(q 2) * \sin(q 3)) - \sin(q 4) * (1.0 * \cos(\alpha 3) * \cos(q 2) * \sin(\alpha 1) * \sin(q 3) - \sin(q 3) * \cos(q 3) * \cos($ $1.0 * \sin(\alpha 1) * \sin(\alpha 2) * \sin(\alpha 3) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(\alpha 3) * \cos(\alpha 3) * \sin(\alpha 1) * \sin(\alpha 2))$ $W_s(19,3) = \cos(\alpha 5) * (\cos(\alpha 4) * (1.0 * \sin(\alpha 3) * \sin(q 3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) *$ $\cos(q2) * \sin(\alpha 1) + \cos(q3) * \sin(\alpha 1) * \sin(\alpha 3) * \sin(q2) + 1.0 * \cos(q4) * \sin(\alpha 4) * (\cos(\alpha 3) * \sin(\alpha 1) + \cos(\alpha 1) * \sin(\alpha 1) * \cos(\alpha 1)$ $\sin(q3)*(\cos(\alpha 1)*\sin(\alpha 2)+\cos(\alpha 2)*\cos(q2)*\sin(\alpha 1))+1.0*\cos(\alpha 3)*\cos(q3)*\sin(\alpha 1)*$ $\sin(q2) + \sin(\alpha 4) * \sin(q4) * (\cos(q3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) - \cos(\alpha 2) * \sin(\alpha 2) + \sin(\alpha 2) * \cos(\alpha 2) * \cos$

 $\sin(\alpha 1) * \sin(q 2) * \sin(q 3))) - \sin(\alpha 5) * \sin(q 5) * (\sin(q 4) * (\cos(\alpha 3) * \sin(q 3) * (\cos(\alpha 1) *$ $\sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) + 1.0 * \cos(\alpha 3) * \cos(q 3) * \sin(\alpha 1) * \sin(q 2)) - \cos(q 4) *$ $(\cos(q_3)*(\cos(\alpha_1)*\sin(\alpha_2)+\cos(\alpha_2)*\cos(q_2)*\sin(\alpha_1))-\sin(\alpha_1)*\sin(q_2)*\sin(q_3)))+1.0*$ $\cos(q5)*\sin(\alpha5)*(\cos(\alpha4)*\cos(q4)*(\cos(\alpha3)*\sin(q3)*(\cos(\alpha1)*\sin(\alpha2)+\cos(\alpha2)*\cos(q2)*)$ $\sin(\alpha 1) + 1.0 * \cos(\alpha 3) * \cos(q 3) * \sin(\alpha 1) * \sin(q 2) - \sin(\alpha 4) * (1.0 * \sin(\alpha 3) * \sin(q 3) * (\cos(\alpha 1) * \sin(\alpha 1) + \cos(\alpha 1) * \sin(\alpha 1) * \cos(\alpha 1$ $\sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) + \cos(q 3) * \sin(\alpha 1) * \sin(\alpha 3) * \sin(q 2)) + 1.0 * \cos(\alpha 4) *$ $\sin(q4)*(\cos(q3)*(\cos(\alpha 1)*\sin(\alpha 2)+\cos(\alpha 2)*\cos(q2)*\sin(\alpha 1))-\sin(\alpha 1)*\sin(q2)*\sin(q3)))$ $W_s(19,4) = \cos(\alpha 5) * (1.0 * \sin(\alpha 4) * \sin(q 4) * (\sin(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2) - 1.0 *$ $\cos(q2) * \sin(\alpha 1) * \sin(\alpha 2)) + \cos(\alpha 3) * \cos(q3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) *$ $\sin(\alpha 1) - 1.0 * \cos(\alpha 3) * \sin(\alpha 1) * \sin(\alpha 2) * \sin(\alpha 3) + \cos(\alpha 4) * \sin(\alpha 4) * (\sin(\alpha 3) * (\cos(\alpha 1) * \sin(\alpha 3) * \sin(\alpha 4) * (\sin(\alpha 3) * \cos(\alpha 4) * \sin(\alpha 4) * (\sin(\alpha 4) * \cos(\alpha 4) * (\cos(\alpha 4) * (\cos(\alpha 4) * \cos(\alpha 4) * (\cos(\alpha 4) * (oo(\alpha 4)$ $\sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) + \cos(q 3) * \sin(\alpha 1) * \sin(q 2))) + 1.0 * \cos(q 5) * \sin(\alpha 5) *$ $(\cos(\alpha 4) * \sin(q 4) * (\sin(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2) - 1.0 * \cos(q 2) * \sin(\alpha 1) * \sin(\alpha 2)) + \cos(\alpha 3) *$ $\cos(q3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) - 1.0 * \cos(\alpha 3) * \sin(\alpha 1) * \sin(q 2) *$ $\sin(q3) + 1.0 * \cos(\alpha 4) * \cos(q4) * (\sin(q3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) + \cos(\alpha 2) * \cos(\alpha$ $\cos(q3) * \sin(\alpha 1) * \sin(q2)) + \sin(\alpha 5) * \sin(q5) * (\cos(q4) * (\sin(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2) - \cos(\alpha 1))) + \sin(\alpha 5) * \sin(\alpha 5) * (\cos(\alpha 1) * \cos(\alpha 2)) + \sin(\alpha 5) * (\cos(\alpha 1) * \cos(\alpha 2)) + \cos(\alpha 2) + \cos(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2)) + \cos(\alpha 2) + \cos(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2)) + \cos(\alpha 2) + \cos(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2)) + \cos(\alpha 2) + \cos(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2)) + \cos(\alpha 2) + \cos(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2)) + \cos(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2)) + \cos(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2)) + \cos(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2)) + \cos(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2)) + \cos(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2)) + \cos(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2)) + \cos(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2)) + \cos(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2)) + \cos(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2)) + \cos(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2)) + \cos(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2)) + \cos(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2)) + \cos(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2)) + \cos(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2)) + \cos(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2)) + \cos(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2)) + \cos(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2)) + \cos(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2)) + \cos(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2)) + \cos(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2)) + \cos(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2)) + \cos(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2)) + \cos(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2)) + \cos(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2)) + \cos(\alpha 2) * (\cos(\alpha 1) * \cos(\alpha 2)) + \cos(\alpha 2) * (\cos(\alpha 1) * \cos(\alpha 2)) + \cos(\alpha 2) * (\cos(\alpha 1) * \cos(\alpha 2)) + \cos(\alpha 2) * (\cos(\alpha 1) * \cos(\alpha 2)) + \cos(\alpha 2) * (\cos(\alpha 1) * \cos(\alpha 2)) + \cos(\alpha 2) * (\cos(\alpha 1) * \cos(\alpha 2)) + \cos(\alpha 2) * (\cos(\alpha 1) * \cos(\alpha 2)) + \cos(\alpha 2) * (\cos(\alpha 1) * \cos(\alpha 2)) + \cos(\alpha 2) * (\cos(\alpha 1) * \cos(\alpha 2)) + \cos(\alpha 2) * (\cos(\alpha 1) * \cos(\alpha 2)) + \cos(\alpha 2) * (\cos(\alpha 1) * \cos(\alpha 2)) + \cos(\alpha 2) * (\cos(\alpha 1) * \cos(\alpha 2)) + \cos(\alpha 2) * (\cos(\alpha 1) * \cos(\alpha 2)) + \cos(\alpha 2) * (\cos(\alpha 1) * \cos(\alpha 2)) + \cos(\alpha 2) * (\cos(\alpha 1) * (\cos(\alpha 1) * \cos(\alpha 2)) + \cos(\alpha 2) * (\cos(\alpha 1) * (\cos(\alpha$ $1.0 * \cos(q2) * \sin(\alpha 1) * \sin(\alpha 2)) + \cos(\alpha 3) * \cos(q3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) *$ $\sin(\alpha 1) - 1.0 * \cos(\alpha 3) * \sin(\alpha 1) * \sin(\alpha 2) * \sin(\alpha 3) - \sin(\alpha 4) * (\sin(\alpha 3) * (\cos(\alpha 1) * \sin(\alpha 2) + \sin(\alpha 3)) + \sin(\alpha 3) * (\cos(\alpha 3) * \sin(\alpha 3) * (\cos(\alpha 3) * \sin(\alpha 3)) + \sin(\alpha 3) * (\cos(\alpha 3) * \sin(\alpha 3)) + \sin(\alpha 3) * (\cos(\alpha 3) * \sin(\alpha 3)) + \sin(\alpha 3) * (\cos(\alpha 3) * \sin(\alpha 3)) + \sin(\alpha 3) * (\cos(\alpha 3) * \sin(\alpha 3)) + \sin(\alpha 3) * (\cos(\alpha 3) * \sin(\alpha 3)) + \sin(\alpha 3) * (\cos(\alpha 3) * \sin(\alpha 3)) + \sin(\alpha 3) * (\cos(\alpha 3) * \cos(\alpha 3)) + \sin(\alpha 3) * (\cos(\alpha 3) * \cos(\alpha 3)) + \sin(\alpha 3) * (\cos(\alpha 3) * \cos(\alpha 3)) + \sin(\alpha 3) * (\cos(\alpha 3) * \cos(\alpha 3)) + \sin(\alpha 3) * (\cos(\alpha 3) * \cos(\alpha 3)) + \cos(\alpha 3) * (\cos(\alpha 3) * \cos(\alpha 3)) + \cos(\alpha 3) * (\cos(\alpha 3) * \cos(\alpha 3)) + \cos(\alpha 3) * (\cos(\alpha 3) * \cos(\alpha 3)) + \cos(\alpha 3) * (\cos(\alpha 3) * (\cos(\alpha 3) * \cos(\alpha 3))) + \cos(\alpha 3) * (\cos(\alpha 3) * (\cos(\alpha 3) * \cos(\alpha 3))) + \cos(\alpha 3) * (\cos(\alpha 3) * (\cos(\alpha 3) * \cos(\alpha 3))) + \cos(\alpha 3) * (\cos(\alpha 3) * (\cos$ $\cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) + \cos(q 3) * \sin(\alpha 1) * \sin(q 2)))$ $W_s(19,5) = 1.0*\sin(\alpha 5)*\sin(q 5)*(\sin(\alpha 4)*(\cos(\alpha 3)*(\cos(\alpha 1)*\cos(\alpha 2)-1.0*\cos(q 2)*)$ $\sin(\alpha 1) * \sin(\alpha 2) - 1.0 * \cos(q 3) * \sin(\alpha 3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) + \sin(\alpha 2) \cos(q 3) * \sin(\alpha 3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 3) * \sin(\alpha 3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 3) * \sin(\alpha 3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 3) * \sin(\alpha 3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 3) * \sin(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 3) * (\cos(\alpha 1) * (\cos(\alpha 1) * \cos(\alpha 1) * (\cos(\alpha 1)$ $\sin(\alpha 1) * \sin(\alpha 3) * \sin(\alpha 2) * \sin(\alpha 3) + \cos(\alpha 4) * \cos(\alpha 4) * (\sin(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2) - \cos(\alpha 4)) * \sin(\alpha 3) * \cos(\alpha 4) * \cos(\alpha 4)$ $1.0 * \cos(q2) * \sin(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 3) * \cos(q3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) *$ $\sin(\alpha 1) - 1.0 * \cos(\alpha 3) * \sin(\alpha 1) * \sin(\alpha 2) * \sin(\alpha 3) - 1.0 * \cos(\alpha 4) * \sin(\alpha 4) * (\sin(\alpha 3) * (\cos(\alpha 1) * \sin(\alpha 3) * \sin(\alpha 4) * \sin(\alpha 3) * (\cos(\alpha 4) * \sin(\alpha 4) * \sin(\alpha 4) * (\sin(\alpha 4) * (\sin(\alpha 4) * \sin(\alpha 4) * (\sin(\alpha 4) * (\cos(\alpha 4) * (o) * (o)$

 $\sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) + \cos(q 3) * \sin(\alpha 1) * \sin(q 2)) + \cos(q 5) * \sin(\alpha 5) *$ $(\sin(q4)*(\sin(\alpha 3)*(\cos(\alpha 1)*\cos(\alpha 2)-1.0*\cos(q2)*\sin(\alpha 1)*\sin(\alpha 2))+\cos(\alpha 3)*\cos(q3)*$ $(\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) - 1.0 * \cos(\alpha 3) * \sin(\alpha 1) * \sin(q 2) * \sin(q 3)) +$ $\cos(q4)*(\sin(q3)*(\cos(\alpha1)*\sin(\alpha2)+\cos(\alpha2)*\cos(q2)*\sin(\alpha1))+\cos(q3)*\sin(\alpha1)*\sin(q2)))$ $W_s(20,1) = 0$ $W_s(20,2) = d4 * (1.0 * \cos(\alpha 3) * \sin(\alpha 1) * \sin(\alpha 2) * \sin(q 2) + \cos(q 2) * \sin(\alpha 1) * \sin(\alpha 3) *$ $\sin(q3) + 1.0 * \cos(\alpha 2) * \cos(q3) * \sin(\alpha 1) * \sin(\alpha 3) * \sin(q2)) + d5 * (\cos(\alpha 4) * (1.0 * \cos(\alpha 3) * \sin(q 3) + 1.0 * \cos(\alpha 4) * (1.0 * \cos(\alpha 4) * \cos(\alpha 4) *$ $\sin(\alpha 1) * \sin(\alpha 2) * \sin(\alpha 2) + \cos(\alpha 2) * \sin(\alpha 1) * \sin(\alpha 3) * \sin(\alpha 3) + 1.0 * \cos(\alpha 2) * \cos(\alpha 3) *$ $\sin(\alpha 1) * \sin(\alpha 3) * \sin(q 2) + \sin(\alpha 4) * \sin(q 4) * (\cos(q 2) * \cos(q 3) * \sin(\alpha 1) - \cos(\alpha 2) * \sin(\alpha 1) *$ $\sin(q2) * \sin(q3)) + 1.0 * \cos(q4) * \sin(\alpha 4) * (1.0 * \cos(\alpha 3) * \cos(q2) * \sin(\alpha 1) * \sin(q3) - 1.0 *$ $\sin(\alpha 1) * \sin(\alpha 2) * \sin(\alpha 3) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(\alpha 3) * \cos(\alpha 3) * \sin(\alpha 1) * \sin(\alpha 2)) + a2 *$ $\cos(q2) * \sin(\alpha 1) + a4 * \cos(q4) * (\cos(q2) * \cos(q3) * \sin(\alpha 1) - \cos(\alpha 2) * \sin(\alpha 1) * \sin(q2) *$ $\sin(q3) - a5 * \sin(q5) * (1.0 * \cos(\alpha 4) * \sin(q4) * (\cos(q2) * \cos(q3) * \sin(\alpha 1) - \cos(\alpha 2) *$ $\sin(\alpha 1) * \sin(q 2) * \sin(q 3)) - \sin(\alpha 4) * (1.0 * \cos(\alpha 3) * \sin(\alpha 1) * \sin(\alpha 2) * \sin(q 2) + \cos(q 2) *$ $\sin(\alpha 1) * \sin(\alpha 3) * \sin(\alpha 3) + 1.0 * \cos(\alpha 2) * \cos(\alpha 3) * \sin(\alpha 1) * \sin(\alpha 3) * \sin(\alpha 2)) + \cos(\alpha 4) *$ $\cos(q4)*(1.0*\cos(\alpha3)*\cos(q2)*\sin(\alpha1)*\sin(q3) - 1.0*\sin(\alpha1)*\sin(\alpha2)*\sin(\alpha3)*\sin(q2) +$ $\cos(\alpha 2) * \cos(\alpha 3) * \cos(q 3) * \sin(\alpha 1) * \sin(q 2)) + a 5 * \cos(q 5) * (\cos(q 4) * (\cos(q 2) * \cos(q 3) * \cos$ $\sin(\alpha 1) - \cos(\alpha 2) * \sin(\alpha 1) * \sin(\alpha 2) * \sin(\alpha 3)) - \sin(\alpha 4) * (1.0 * \cos(\alpha 3) * \cos(\alpha 2) * \sin(\alpha 1) *$ $\sin(q3) - 1.0 * \sin(\alpha 1) * \sin(\alpha 2) * \sin(\alpha 3) * \sin(q 2) + \cos(\alpha 2) * \cos(\alpha 3) * \cos(q 3) * \sin(\alpha 1) *$ $\sin(q2)) - a4 * \sin(q4) * (1.0 * \cos(\alpha 3) * \cos(q2) * \sin(\alpha 1) * \sin(q3) - 1.0 * \sin(\alpha 1) * \sin(\alpha 2) *$ $\sin(\alpha 3) * \sin(q 2) + \cos(\alpha 2) * \cos(\alpha 3) * \cos(q 3) * \sin(\alpha 1) * \sin(q 2)) + a 3 * \cos(q 2) * \cos(q 3) *$ $\sin(\alpha 1) + 1.0 * d3 * \sin(\alpha 1) * \sin(\alpha 2) * \sin(\alpha 2) - a3 * \cos(\alpha 2) * \sin(\alpha 1) * \sin(\alpha 2) * \sin(\alpha 3)$ $W_s(20,3) = d4*(1.0*\sin(\alpha 3)*\sin(\alpha 3)*(\cos(\alpha 1)*\sin(\alpha 2)+\cos(\alpha 2)*\cos(\alpha 2)*\sin(\alpha 1))+$

```
\cos(q3) * \sin(\alpha 1) * \sin(\alpha 3) * \sin(q2)) + d5 * (\cos(\alpha 4) * (1.0 * \sin(\alpha 3) * \sin(q3) * (\cos(\alpha 1) *
  \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) + \cos(q 3) * \sin(\alpha 1) * \sin(\alpha 3) * \sin(q 2)) + 1.0 * \cos(q 4) *
  \sin(\alpha 4) * (\cos(\alpha 3) * \sin(q 3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) + 1.0 * \cos(\alpha 3) *
  \cos(q3) * \sin(\alpha 1) * \sin(q2)) + \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)) - a4 * \sin(q4) * (\cos(\alpha 3) * \sin(q3) * (\cos(\alpha 1) * \sin(q3) * \sin(q3) * \cos(\alpha 1) * \sin(q3) * \sin(q3) * \cos(\alpha 1) * \sin(q3) * \cos(\alpha 1) * \sin(\alpha 1) * \cos(\alpha 1) * \sin(\alpha 1) * \cos(\alpha 1) * \cos(\alpha
  \sin(\alpha 2) + \cos(\alpha 2) * \cos(\alpha 2) * \sin(\alpha 1)) + 1.0 * \cos(\alpha 3) * \cos(\alpha 3) * \sin(\alpha 1) * \sin(\alpha 2)) + a4 *
  \cos(q4) * (\cos(q3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) - \sin(\alpha 1) * \sin(q 2) *
  \sin(q3)) -a5*\sin(q5)*(\cos(\alpha 4)*\cos(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) - \sin(\alpha 4) * (1.0 * \sin(\alpha 3) * \sin(\alpha 1)) + 1.0 * \cos(\alpha 3) * \cos(\alpha 3) * \sin(\alpha 1) + \cos(\alpha 1) + \cos(
  \sin(q3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) + \cos(q 3) * \sin(\alpha 1) * \sin(\alpha 3) *
  \sin(q2) + 1.0 * \cos(\alpha 4) * \sin(q4) * (\cos(q3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) - \cos(\alpha 2) * \cos(\alpha 
  \sin(\alpha 1) * \sin(q 2) * \sin(q 3))) - a 5 * \cos(q 5) * (\sin(q 4) * (\cos(\alpha 3) * \sin(q 3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 3) * \sin(\alpha 3))))
  \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1) + 1.0 * \cos(\alpha 3) * \cos(q 3) * \sin(\alpha 1) * \sin(q 2) - \cos(q 4) * (\cos(q 3) * \sin(\alpha 1) * \cos(q 3) * \cos(q 3) * \sin(\alpha 1) * \cos(q 3) * \cos(q
    (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) - \sin(\alpha 1) * \sin(q 2) * \sin(q 3))) + a 3 * \cos(q 3) *
  (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) - a 3 * \sin(\alpha 1) * \sin(q 2) * \sin(q 3)
                                                     W_s(20,4) = d5 * (1.0 * \sin(\alpha 4) * \sin(q 4) * (\sin(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2) - 1.0 * \cos(q 2) *
  \sin(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 3) * \cos(\alpha 3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(\alpha 2) * \sin(\alpha 1)) - \cos(\alpha 3) * \cos(\alpha 3) *
  1.0 * \cos(\alpha 3) * \sin(\alpha 1) * \sin(\alpha 2) * \sin(\alpha 3)) + \cos(\alpha 4) * \sin(\alpha 4) * (\sin(\alpha 3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 3)) * \sin(\alpha 3) * (\cos(\alpha 1) * \sin(\alpha 2) * (\cos(\alpha 1) * \sin(\alpha 3)) * (\cos(\alpha 1) * \cos(\alpha 1)) * (\cos(\alpha 1) * (\cos(\alpha 1) * \cos(\alpha 1)) * (\cos(\alpha 1) * (\cos(\alpha 1) * \cos(\alpha 1)) * (\cos(\alpha 1) * (\cos(\alpha 1) * \cos(\alpha 1)) * (\cos(\alpha 1) * (\cos(\alpha 1) * (\cos(\alpha 1) * (\cos(\alpha 1) * (\cos(\alpha 1))) * (\cos(\alpha 1) * (\cos(\alpha 1) * (\cos(\alpha 1) * (\cos(\alpha 1))) * (\cos(\alpha 1) * (\cos(\alpha 1) * (\cos(\alpha 1))) * (\cos(\alpha 1) * (\cos(\alpha 1) * (\cos(\alpha 1))) * (\cos(\alpha 1) * (\cos(\alpha 1) * (\cos(\alpha 1))) * (\cos(\alpha 1) * (\cos(\alpha 1) * (\cos(\alpha 1))) * (\cos(\alpha 1) * (\cos(\alpha 1) * (\cos(\alpha 1))) * (\cos(\alpha 1) * (\cos(\alpha 1) * (\cos(\alpha 1))) * (\cos(\alpha 1) * (\cos(\alpha 1))) * (\cos(\alpha 1) * (\cos(\alpha 1) * (\cos(\alpha 1))) * (\cos(\alpha 1) * (\cos(\alpha 1
  \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) + \cos(q 3) * \sin(\alpha 1) * \sin(q 2))) - a 5 * \sin(q 5) * (\cos(\alpha 4) * \sin(q 4) * \sin(q 4)))
  (\sin(\alpha 3)*(\cos(\alpha 1)*\cos(\alpha 2)-1.0*\cos(q 2)*\sin(\alpha 1)*\sin(\alpha 2))+\cos(\alpha 3)*\cos(q 3)*(\cos(\alpha 1)*\cos(q 3)*\cos(q 3)
  \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) - 1.0 * \cos(\alpha 3) * \sin(\alpha 1) * \sin(q 2) * \sin(q 3)) + 1.0 *
  \cos(\alpha 4) * \cos(q 4) * (\sin(q 3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) + \cos(q 3) *
  \sin(\alpha 1) * \sin(q 2)) + a 5 * \cos(q 5) * (\cos(q 4) * (\sin(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2) - 1.0 * \cos(q 2) *
\sin(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 3) * \cos(\alpha 3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(\alpha 2) * \sin(\alpha 1)) - \cos(\alpha 3) * \cos(\alpha 3) *
```

 $\begin{aligned} &1.0 * \cos(\alpha 3) * \sin(\alpha 1) * \sin(q 2) * \sin(q 3)) - \sin(q 4) * (\sin(q 3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) + \cos(q 3) * \sin(\alpha 1) * \sin(q 2))) - a 4 * \sin(q 4) * (\sin(q 3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) + \cos(q 3) * \sin(\alpha 1) * \sin(q 2)) + a 4 * \cos(q 4) * (\sin(\alpha 3) * (\cos(\alpha 1) * \cos(\alpha 2) - 1.0 * \cos(q 2) * \sin(\alpha 1) * \sin(\alpha 2)) + \cos(\alpha 3) * \cos(q 3) * (\cos(\alpha 1) * \sin(\alpha 2) + \cos(\alpha 2) * \cos(q 2) * \sin(\alpha 1)) - 1.0 * \cos(\alpha 3) * \sin(\alpha 1) * \sin(q 2) * \sin(q 3)) \end{aligned}$

 $W_{s}(20,5) = a5*\cos(q5)*(\sin(\alpha4)*(\cos(\alpha3)*(\cos(\alpha1)*\cos(\alpha2)-1.0*\cos(q2)*\sin(\alpha1)*\sin(\alpha2)) - 1.0*\cos(q3)*\sin(\alpha3)*(\cos(\alpha1)*\sin(\alpha2)+\cos(\alpha2)+\cos(\alpha2)*\cos(q2)*\sin(\alpha1)) + \sin(\alpha1)*\sin(\alpha3)*\sin(q2)*\sin(q3)) + \cos(\alpha4)*\cos(q4)*(\sin(\alpha3)*(\cos(\alpha1)*\cos(\alpha2)-1.0*\cos(q2)*\sin(\alpha1)) - 1.0*\cos(\alpha3)*\sin(\alpha2) + \cos(\alpha3)*\sin(\alpha2)*\sin(\alpha3) + \sin(\alpha2) + \cos(\alpha3)*\sin(\alpha2) + \cos(\alpha3)*\sin(\alpha2)*\sin(\alpha3) + \cos(\alpha3)*\sin(\alpha3) + \cos(\alpha3)*\cos(\alpha3) + \cos(\alpha3)*\sin(\alpha3) + \cos(\alpha3)*\cos(\alpha3) + \cos(\alpha3) + \cos(\alpha3)*\sin(\alpha3) + \cos(\alpha3)*\cos(\alpha3) + \cos(\alpha3) +$