PR-2

Comfort Estimation During Lift-up Based on Contact Force and Joint Torque Estimation

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In our research center, we have developed a nursing-care assistant robot named RIBA [1, 2]. In this research, in order to realize stable and comfortable lifting-up and transfer motion automatically, a 4-link model for dynamics analysis is used to predict user's comfortable feeling, as shown in Fig. 1. Human head, upper-body, thigh and leg are modeled as rigid links and rotated by neck, hip and knee joints. This model can estimate the forces from robot (normal forces (F_1, F_2) and friction forces (f_1, f_2)) and estimate the torques from human joints (M_1, M_2, M_3) based on the posture and lifting status of human and robot. Estimated forces and torques are also used to calculate the comfort (v) of human as follows:

$$v = \omega_1\left(\frac{M_1}{M_{1\max}}\right) + \omega_2\left(\frac{M_2}{M_{2\max}}\right) + \omega_3\left(\frac{M_3}{M_{3\max}}\right) + \omega_4\left(\frac{F_1}{F_{1\max}}\right) + \omega_5\left(\frac{F_2}{F_{2\max}}\right) + \omega_6\left(\frac{f_1}{f_{1\max}}\right) + \omega_7\left(\frac{f_2}{f_{2\max}}\right) \quad (1)$$

where $F_{i\max}$and $M_{i\max}$ is maximum force and torque when human body is horizontal and there are not any lifting forces from robot. $\boldsymbol{\omega}$ is the weight which shows the effect of comfortable feeling of each lifting forces and joint torques.

We carried out some experiments to check the developed model and method. Robot lifted subjects up using two different motions. We measured subjects' EMG signal during lift-up and asked about their comfortable feeling after experiments. Most estimated joint torques had same change trends with measured EMG signal (five out of seven subjects). And most estimated comfort also had same change trends with the result of questionnaires (six out of ten subjects) (Table 1). Different estimated trends were mainly obtained from small changes. These quantitative and qualitative comparison results show that the developed model and estimating method are effective for comfort estimation during lift-up. In the future, we will find a better weight $\boldsymbol{\omega}$ and use this model and our estimating method to make robot find a best lifting-up motion automatically.

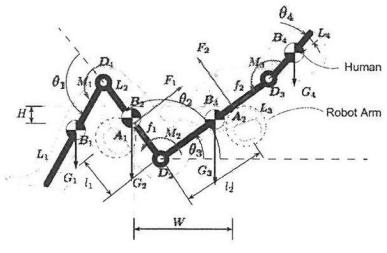

Fig. 1. 4-Link Human-RIBA model during lift-up

Tab. 1. Change of Comfort Level From Questionnaire and Estimation

	Before	After	Change	Simu.	
Sub1	5	4	0.80	0.91	○
Sub2	5	2	0.40	0.55	○
Sub3	4	5	1.25	0.84	×
Sub4	3	2	0.67	1.07	×
Sub5	3	2	0.67	0.60	○
Sub6	4	3	0.75	0.92	○
Sub7	4	3	0.75	0.27	○
Sub8	4	1	0.25	1.21	×
Sub9	3	4	1.33	1.41	○
Sub10	6	5	0.83	1.13	×

○: Same change trend
×: Different change trend

References

[1] T. Mukai, S. Hirano, H. Nakashima, Y. Sakaida, And S. Guo, "Realization and Safety Measures of Patient Transfer by Nursing-Care Assistant Robot RIBA with Tactile Sensors", *J. Robotics and Mechatronics*, **77**(782), 116-124 (2011).

[2] Z. Zyada, Y. Hayakawa, and S. Hosoe, "Kinematic analysis of a two-link object for whole arm manipulation", *the 9th WSEAS Int. Conf. on Signal Processing, Robotics and Automation*, 139-145 (2010).