Design of a new shoulder joint mechanism for an upper-limb exoskeleton robot.

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Abstract

This paper proposes an effective shoulder joint mechanism for an upper-limb exoskeleton robot. Human glenohumeral joint moves in 3-dimention in accordance with the movement of the upper-limb such as the shoulder flexion/extension and abduction/adduction motion. In order to reduce the difference between the human glenohumeral joint position and the exoskeleton shoulder joint position, we propose a passive compensation mechanism which consists of links and sliders. This mechanism can imitate the movement of human glenohumeral joint without additional motors.

Keywords: exoskeleton robot, shoulder joint, glenohumeral joint

1. Introduction

Recently, the progress in robotics and mechatronics technology brings much benefit not only in industries, but also in medicine and welfare. In the medical field, applications of robot supporting operation are spreading such as less invasive surgery, telemedicine services and high precision medical treatment. In the meantime, an exoskeleton power assist robot is expected in the field of welfare. In Japan, especially, researches on exoskeleton robots focus on caregivers support, rehabilitation due to the declining birthrate and aging society.

However, it is not easy to design an exoskeleton power assist robot because the movements of human joints are complex. In an upper limb, a shoulder joint movement is especially complicated. Therefore developed shoulder joints for exoskeleton robots are intricate. IntelliArm[1, 2] and MGA[3] have some additional motors to follow the movement of the human upper limb. Its flexibility and precision are good, but its weight and costs are increased. For simplify the mechanisms, SUEFUL-7[4, 5] use links and sliders to follow the movement without adding motors. Its weigh is light, but the following of motion is not perfect. This paper proposes a shoulder joint mechanism for an upper-limb exoskeleton robot with links and sliders.

2. The human glenohumeral joint

The human shoulder joint, called a glenohumeral joint, moves in 3-dimention by the movement of the upper-limb such as the shoulder flexion/extension and abduction/adduction motion. Several measurement data about shoulder joints' angles from a medical point of

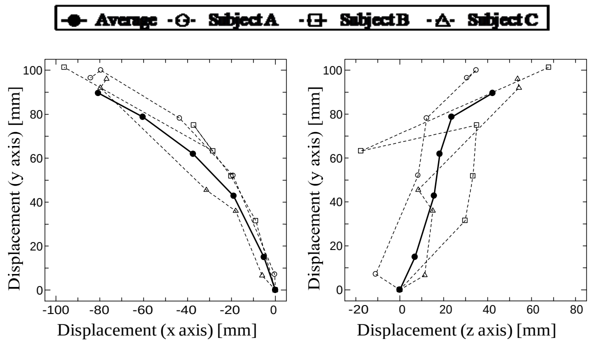

Fig. 1. Measurement results (shoulder abduction motion)

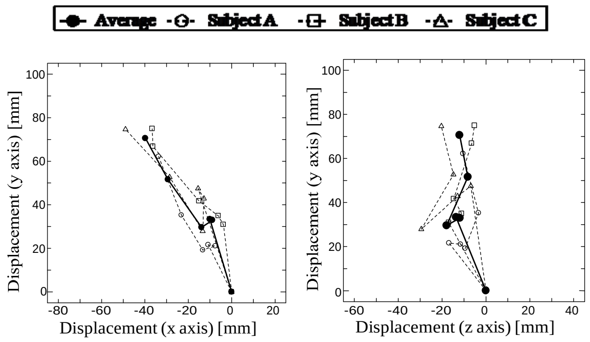

Fig. 2. Measurement results (shoulder flexion motion)

view are reported in Ref. 6. Kiguch *et.al*[7] measured the coordinate data of glenohumeral joint.

Their measurement data is shown in Figs 1 and 2. In the shoulder abduction motion, the glenohumeral joint moves to inside and high position in x-y plane. In the shoulder flexion motion, the glenohumeral joint moves to high position in z-y plane.

In this paper, a new shoulder joint mechanism for an exoskeleton robot is designed based on the coordinates measured by Kiguchi *et.al.*

3. Mechanisms of the robot’s shoulder joint

This shoulder joint mechanism use links and sliders to follow the movement and to save its weight. This robot shoulder joint has three DOF (Figure 3) for three DOF of the human shoulder joint. The 1st axis is used for shoulder horizontal abduction/adduction motion. The 2nd axis is used for shoulder flexion/extension motion. The 3rd axis is used for shoulder internal/external rotation motion. Pulleys are rotated by wires around the

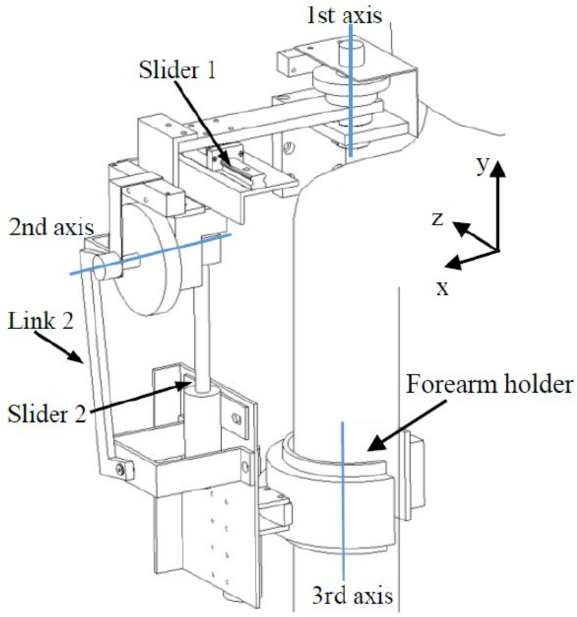

Fig. 3. Proposed shoulder joint

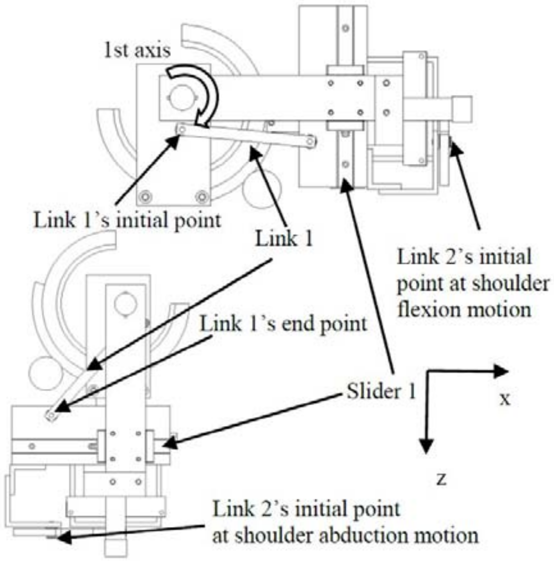

Fig. 4. Top mechanism at shoulder horizontal flexion 0 deg. and 90 deg. (Top view)

1st and 2nd axis. A motor rotates the forearm holder around the 3rd axis.

The angles of the 1st and 2nd axis are limited in 0 deg. to 90 deg. for safety. Two mechanisms linked the 1st and 2nd axis reduce the error between the human

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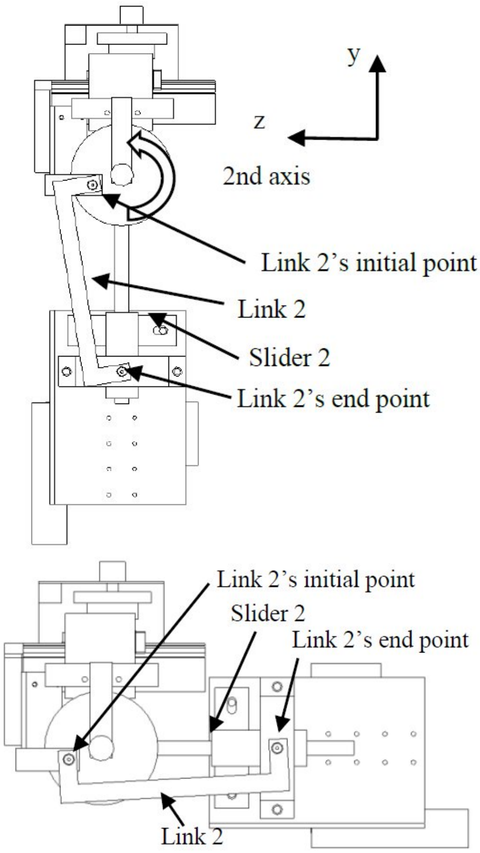

Fig. 5. Side mechanism at shoulder flexion 0 deg. and 90 deg. (Side view)

glenohumeral joint position and the exoskeleton shoulder joint position. Figure 4 shows the top mechanism.
The link 1 and slider 1 change the position of the link 2's initial point. This difference of the positions of link 2's initial point enable this exoskeleton shoulder joint to follow both the human shoulder flexion motion and shoulder abduction motion. The side mechanism is shown in Fig 5. The link 2 changes the length of the slider 2. The slider 2 connect its forearm holder. Shrinking the length of slider 2 means that the center of the exoskeleton robot shoulder joint moves to up or inside.

4. Simulation in 3D CAD

This proposed mechanism is evaluated by a simulation in 3D CAD. The coordinates of its points when the angle of horizontal flexion is 0 deg. and the angle of shoulder flexion is 0 deg. show in Table 1. The position of the link

Table 1. The coordinates of the robot

name	axis	value [mm]
Human glenohumeral joint (the origin)	x	0
	y	0
	z	0
1st axis	x	0
	z	0
Link 1initial point	x	0
	z	28
Link 1end point	x	112.5
	z	38.6
Length of Link 1		113
2nd axis	y	10
	z	48
Link 2 initial point	y	38
	z	38
Link 2 end point	y	-140
	z	10
Length of Link 2		184

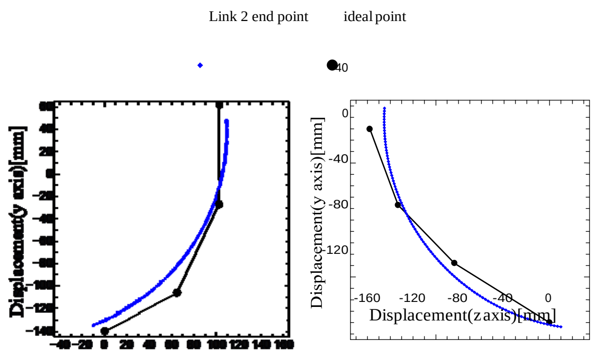

Fig. 6. Results of the simulations
(Right: shoulder flexion motion,
Left: shoulder abduction motion)

2 initial point is limited. The z value of the point must be bigger than 38mm because of its mechanical interference. The results of the simulation shows in Figure 6. The blue data means the path traced by a moving Link 2 end point. The black data means ideal point calculated from the human measured value. The difference between the positon of human glenohumeral joint and the position of the exoskeleton shoulder joint is less than 25 mm.

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5. Conclusion

In this paper, the simple following exoskeleton shoulder joint for an upper-limb power assist robot is proposed. The proposed shoulder joint mechanism enable the exoskeleton robot to follow the movement of human glenohumeral joint and reduce the difference of these joints. The effectiveness of the proposed mechanism is demonstrated by 3D CAD simulations. We are presently assembling a real robot with this mechanism.

6. References

1. Y. Ren, H. -S. Park, L. –Q. Zhang, *Developing a whole-arm exoskeleton robot with hand opening and closing mechanism for upper limb stroke rehabilitation.* In: IEEE international conference on rehabilitation robotics. 2009.
p. 761–765.
2. Y. Ren, H. -S. Park, L. –Q. Zhang, *IntelliArm: an exoskeleton for diagnosis and treatment of patients with neurological impairments.* In: Biennial IEEE/RAS-EMBS international conference on biomedical robotics and biomechatronics. 2008. p.109–114.
3. C. Carignan, J. Tang, S. Roderick, *Development of an exoskeleton haptic interface for virtual task training.* In: IEEE/RSJ international conference on intelligent robots and systems. 2009. p. 3697–3702.
4. Gopura RARC, K. Kazuo, Y. Yi, *SUEFUL-7: a 7DOF upper-limb exoskeleton robot with muscle-model-oriented EMG-based control.* In: IEEE/RSJ international conference on intelligent robots and systems. 2009. p. 1126–1131.
5. K. Kazuo, M. H. Rahman, M. Makoto, T. Kenbu, *Development of a 3DOF mobile exoskeleton robot for human upper-limb motion assist.* Robotics and Autonomous Systems 2008; 56:678–691.
6. N. K. Poppen, P. S. Walker, *Normal and abnormal motion of the shoulder*, J Bone Joint Surg Am. 1976;58:195-201.12
7. K. Kazuo, K. Kenryu, H. Yoshiaki, *Design of a 7DOF upper-limb power-assist exoskeleton robot with moving shoulder joint mechanism.* In: Robotics and Biomimetics (ROBIO), 2011 IEEE International Conference on. IEEE, 2011. p. 2937-2942.

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