Paper:

Controller Adjustment of an Exoskeleton Robot for Shoulder Motion Assistance

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[Received October 22, 2003; accepted March 11, 2004]

We are developing exoskeleton robots to realize human shoulder motion assistance for the physically weak. In this paper, we propose controller adjustment for the controller of the exoskeleton robot for human shoulder motion assistance. Motion assistance in the entire movable range of the exoskeleton is realized with a few teaching motion patterns using the proposed controller adjustment. Muscle activity (electromyography) during shoulder motion and motion error between desired user shoulder motion and the measured assisted shoulder motion are evaluated.

Keywords: exoskeleton robot, human shoulder, motion assistance

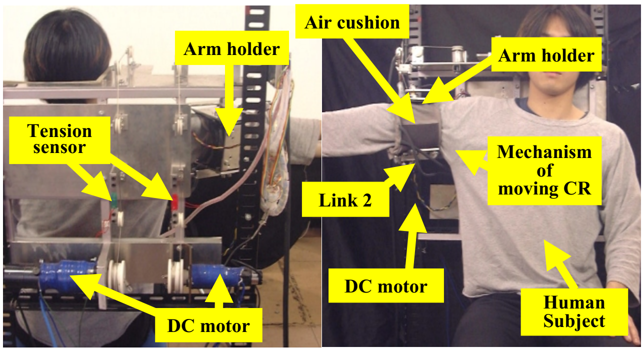


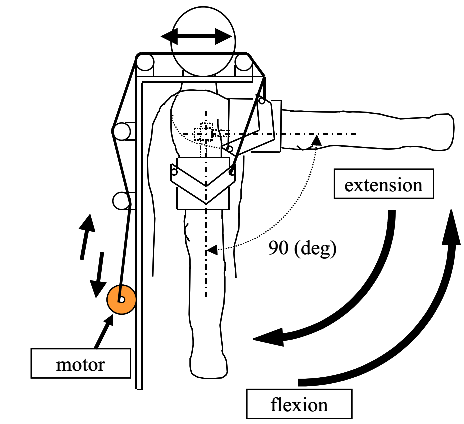
Fig. 1. Architecture of the exoskeleton robot.

1. Introduction

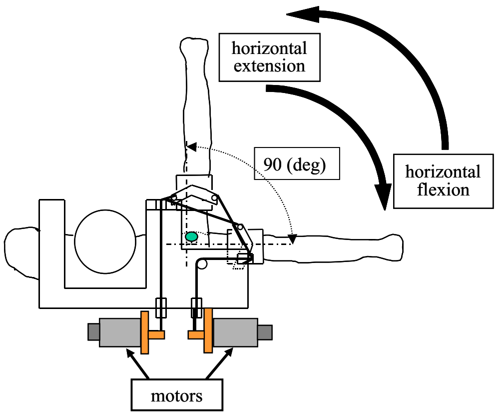
We are developing exoskeleton robots to realize human shoulder motion assistance (power assistance) for the physically weak elderly, slightly disabled, and injured [1-5]. The robot is automatically controlled with skin surface electromyogram (EMG) signals of a user's shoulder muscles that directly reflect the user's intended motion, enabling natural motion assistance to be realized for the physically weak without learning driving to control the robot. EMG signals are often used as input to robots [6-8]. They are, however, affected by the user's physical and physiological condition [9,10], making it difficult to obtain the same EMG signals even for the same motion with the same user. EMG signal levels may also differ greatly between users. To solve such problems, the robot controller must be flexible and adaptable enough to adjust itself to the robot user's physique and physiology. We use fuzzy neurocontrol to realize an effective controller for the exoskeleton robot.

When the controller is adjusted to the user's physique and physiology, patterns of EMG signals for all shoulder motion in the entire movable range of the exoskeleton robot must be given for adaptation, despite the time it consumes and the burden on the user. We propose effective controller adjustment requiring few teaching motions for the fuzzy-neuro controller of the exoskeleton robot for human shoulder motion assistance paper. In proposed adjustment, muscle activity (EMG) during shoulder motion and motion error between desired user shoulder motion and measured assisted motion is evaluated. Adjustment of muscle activity is the same as adjustment of power assistance in this study. It is vital in power assistance for the physically weak to adjust assistance based on physical, physiological, and rehabilitation considerations. To evaluate muscle activity, the direction of shoulder motion and allocation of shoulder muscles are taken into account. We propose controller adaptation for the entire movable range of the exoskeleton robot with a few specified shoulder motions, i.e., vertical flexion/extension and horizontal flexion/extension of the shoulder.

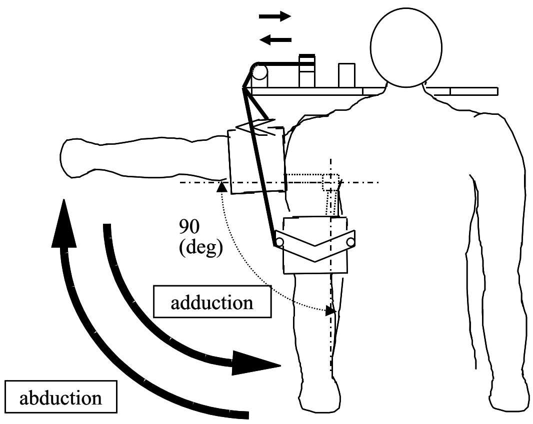
This paper is organized as follows: The architecture of the exoskeleton robot is explained in Section 2. Section 3 details the controller and adaptation . Section 4 evaluates the effectiveness of proposed adjustment , and Section 5 summarizes conclusions.



(a) Side view

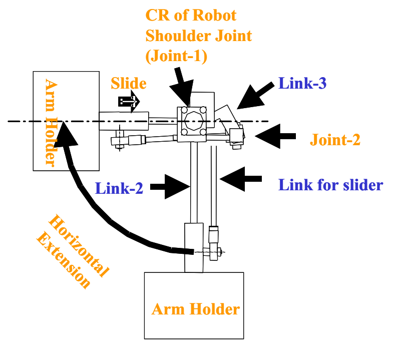


(b) Top view

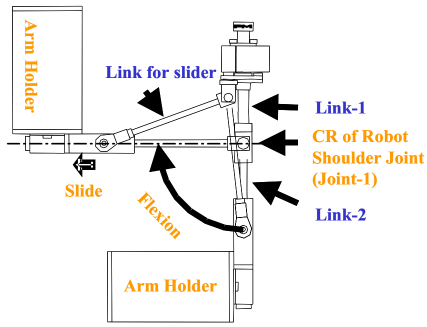


(c) Front view

Fig. 2. Movable range of the exoskeleton robot.



Shoulder Horizontal Extension Motion
(Top view)



Shoulder Flexion Motion
(Side view)

Fig. 3. Mechanism of the moving center of rotation.

2. Exoskeleton Robot for Shoulder Motion Assistance

The architecture of the exoskeleton robot (**Fig.1**) consists of a frame, two main links, an arm holder, two DC motors [Harmonic Drive System Co.], drive wires, wire tension sensors (strain gauges), and the mechanism of the moving center of rotation (CR) of the shoulder joint. The exoskeleton robot is attached directly to the user and assists the user's shoulder joint motion (flexion-extension and abduction-adduction) (**Fig.2**) by manipulating the user's upper-arm with the arm holder, which is fixed on the slider on link 2. The user's upper arm is moved by controlling arm holder motion with DC motors via driving wires. The inside of the arm holder is covered by an air cushion in which air pressure is adjustable to fit any upper arm size. The flexibility of the air cushion softens the motion difference between the robot and user caused by the difference in the CR of shoulder joints. Given that many physically weak use wheelchairs, heavy parts of the exoskeleton robot, i.e., DC motors, are installed on the chair and other parts directly attached to the user.

The human shoulder (glenohumeral) joint consists of muscles such as the deltoid, biceps, triceps, pectoralis major, infraspinatus, and teres major that move in 3 degrees of freedom (DOF) (flexion-extension, abduction-adduction, and internal-external rotation). The human shoulder complex provides 7 DOF for arm movement because it consists of the scapula, clavicle, and humerus and moves conjointly [11]. Since the CR of the glenohumeral joint is dislocated by shoulder motion, the moving CR of the shoulder joint must be applied to the exoskeleton robot. In this robot, the distance between