Motion Range and Control of an Escort-Type Upper Limb Rehabilitation Robot for Assisting Reaching Motion

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1. Research Objective

Endeffector-Type robots is better to control the hand position, while Exoskeleton robots are easier to support the arm posture. What kind robot structure is suitable to guide reaching motion?

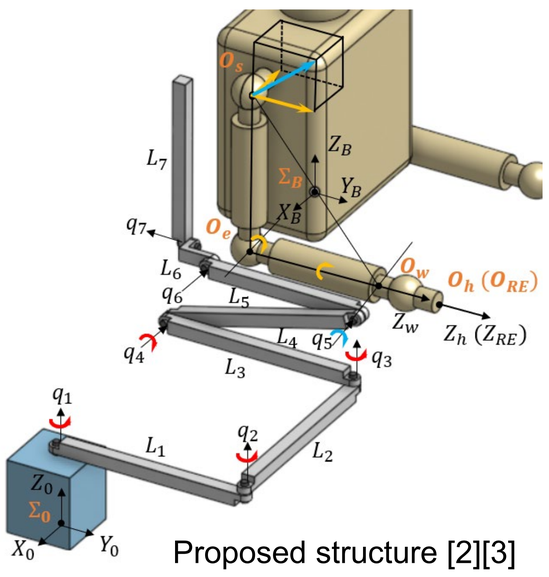
To address this problem, the escort-type rehabilitation robot structure has been proposed [1].

The objective of this study is then to clarify that this escort-type rehabilitation robot is suitable for guiding reaching motion.

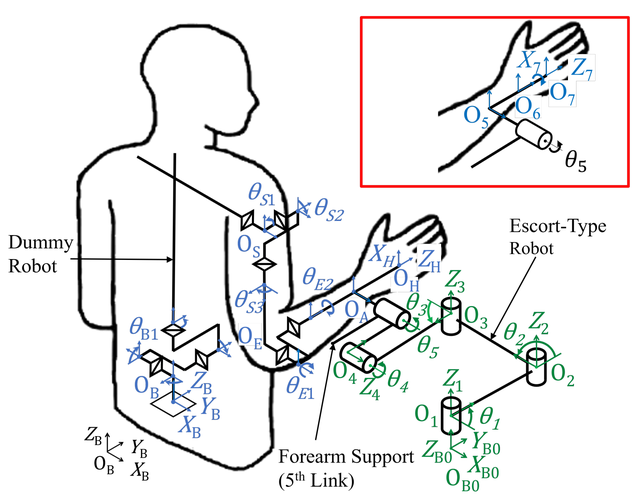
2. Proposed Escort-Type Rehabilitation Robot

This escort-type robots (1) can provide arm posture guidance as well as hand position guidance, and (2) does not constrain the shoulder joint position, thus allowing functional reach.

[1] K. Nagai, K. Kitayama, K. Ito, R. C. Loureiro, and W. S. Harwin, “Structural analysis of an escort type rehabilitation robot,” J. Robot. Soc. Jpn., vol. 30, pp. 53–61, 2012 (in JPN).
[2] S. Li and K. Nagai, “Kinematical analysis of an upper limb rehabilitation robot to assist in reaching motions,” RSJ, no. 1J3-02, 2021 (in JPN).
[3] —, “The role of the passive joints to ensure user safety in escort-type rehabilitation robots for upper limb,” RSJ, no. 4D3-01, 2022 (in JPN).

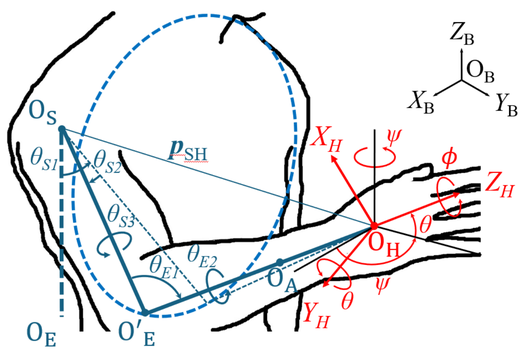


Proposed structure [2][3]

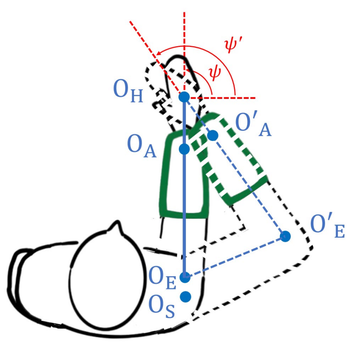


Escort-Type rehab. robot and dummy robot

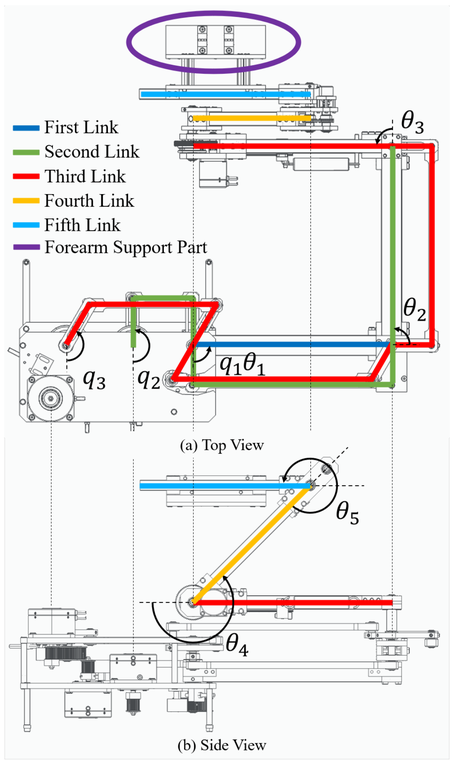
3. How Escort-Type Rehabilitation Robot works



Hand orientation and arm posture



Relation between ψ and arm posture



Escort-type rehab. robot kinematic model

4. Experiments

Desired reaching motion:

$t = 0 \sim 1$ [s]: $\psi = 90° \rightarrow 120°$
$t = 1 \sim 2$ [s]: $\psi = 120°$ (max. value)
$t = 2 \sim 3$ [s]: $\psi = 120° \rightarrow 90°$
$t = 3 \sim 4$ [s]: $\psi = 90°$ (initial value)

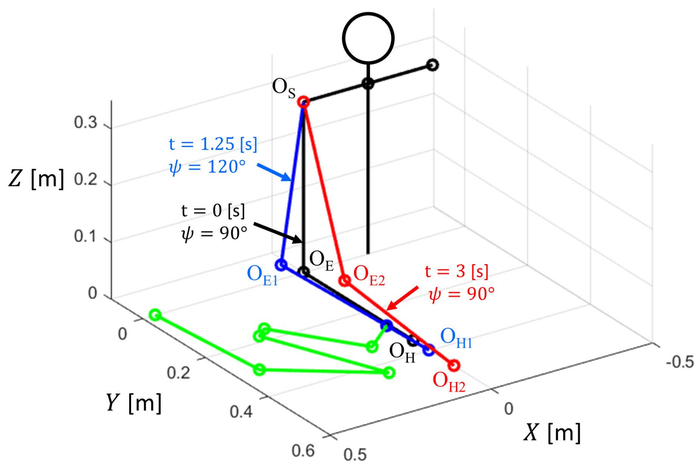
Initial position: $r_{OH} = \begin{bmatrix} x_{OH} \\ y_{OH} \\ z_{OH} \end{bmatrix} = \begin{bmatrix} 0 \\ 0.35 \\ 0 \end{bmatrix}$

Final position: $r_{OH2} = \begin{bmatrix} x_{OH2} \\ y_{OH2} \\ z_{OH2} \end{bmatrix} = \begin{bmatrix} 0 \\ 0.48 \\ 0 \end{bmatrix}$

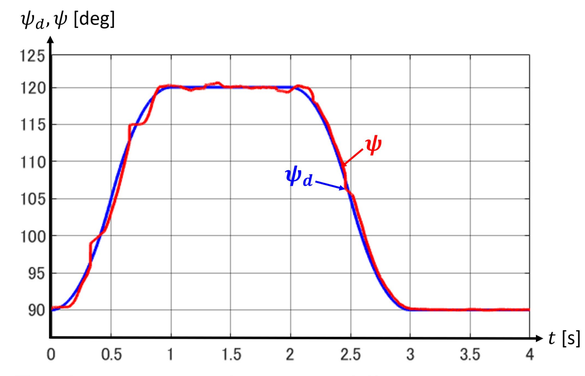
Four active joints (q_1 to q_4) guides the hand position O_H (x, y, z) and yaw angle ψ, a part of arm posture.

One passive joint (q_5) allows changes of shoulder position O_H with two DOF motion by θ_{E1} and θ_{E2}.

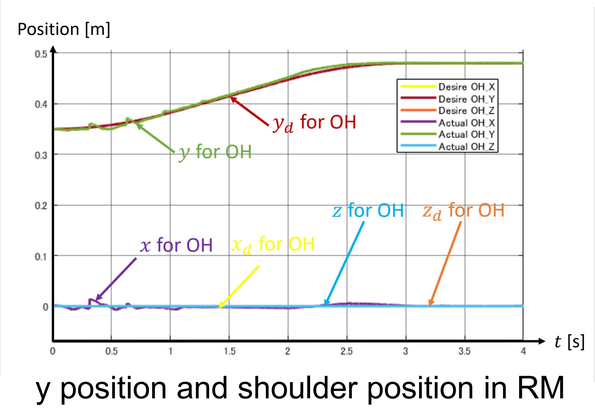
The desired values of x, y, z and ψ are given to the controller to guide the reaching motion and functional reach.



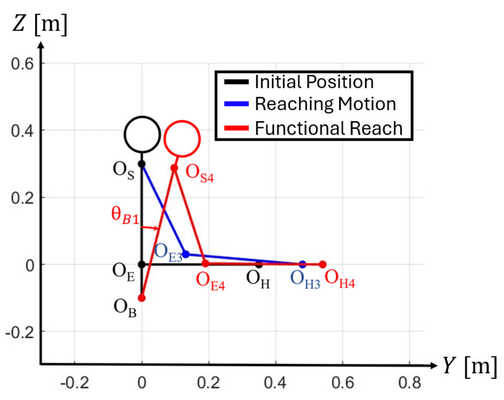
Arm postures in desired reaching motion



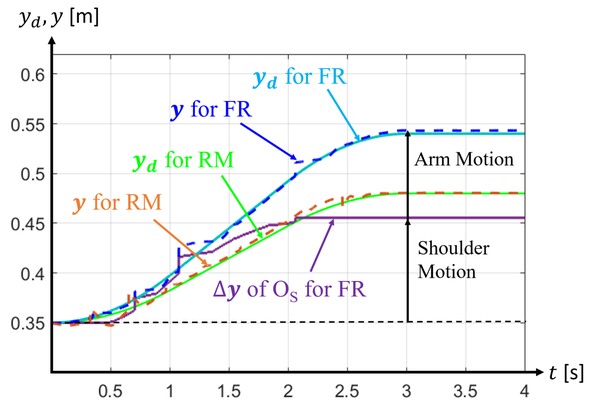
Desire yaw angle ψ_d and its response ψ



y position and shoulder position in RM



Reaching Motion (RM) and Functional Reach (FR)



y position and shoulder position in RM and FR

5. Conclusion

1) The method for deriving the motion range of an escort-type rehabilitation robot for the upper limb was clarified.

   In the escort-type rehabilitation robot with passive joints, the arm postures of both the patient and the robot will be determined when the robot is attached to the patient’s arm.

2) The escort-type rehabilitation robot for upper limbs was found to have the following two features:

   (1) The structure enables simultaneous hand position guidance and arm posture guidance in reaching motion,

   (2) The structure allows functional reach since the shoulder position is not restrained during the reaching motion.