ERU Engineering Research Unit University of Moratuwa Sri Lanka

Bimanual Tele rehabilitation Robot

K. L. M. Perera
Department of Electrical Engineering
University of Moratuwa
Moratuwa, Sri Lanka
madhushanlk@gmail.com

T. I. Hettiarachchi
Department of Electrical Engineering
University of Moratuwa
Moratuwa, Sri Lanka
thiliniimalka03@gmail.com

J.A.A.S. Kumara
Department of Electrical Engineering
University of Moratuwa
Moratuwa, Sri Lanka
arunasadeepa99@gmail.com

R. M. M. Ruwanthika
Department of Electrical Engineering
University of Moratuwa
Moratuwa, Sri Lanka
ruwanthim@uom.lk

Arunya P. Senadeera S. D.
Department of Electrical Engineering
University of Moratuwa
Moratuwa, Sri Lanka
arunya@ait.ac.th

Keywords — Rehabilitation, Bimanual, Medical robot, Multiple exercises

I. INTRODUCTION

Post-stroke patients lose their interlimb coordination and ability to do bimanual activities. This is common for arms, and usually, patients get one arm paretic. This is a heavy burden since everyday activities need both hands to do. For recovery, they need intensive bimanual therapy. The robotic approach is more effective than traditional rehabilitation for this kind of therapy. A bimanual master-slave robotic system can be used to do simultaneous exercises for patients' both hands. Our focus is to implement the two most basic and critical movements into this robot. One is Flexion and Extension, and the other is Internal and external rotation.

Stroke is one of the conditions that causes long-term disabilities. This causes a lot of struggles for patients to recover. To overcome that and speed up the recovery we propose a robotic approach, with reduced dependency on a therapist and increased repeatability and robustness.

When doing these exercises, the patient's shoulder must be in a relaxed position. Otherwise, the generated torques will depend on the shoulder position. Hence there must be adjustments for varying arm lengths as it changes the position of the elbow joint. Also, we are going to implement two exercises which are done in perpendicular planes into one 1 DOF (Degrees of Freedom), robot. And we need to provide methods to change the motor orientation for that.

II. LITERATURE REVIEW

As stated in [1] stroke is a condition that causes long-term disabilities and according to [2], 30% – 60% of patients are able to walk but unable to regain full functionality of arms. Early rehabilitation is a great help in recovering such conditions as for [3].

According to [4], bimanual physical therapy is crucial for patients with disabilities limited to one side of the body. The proposed robotic device aims to restore bimanual coordination. The cost-effectiveness and reduced dependence on a therapist's physical presence enhance the appeal of the device. Following this, [5] emphasizes the significance of rehabilitation robots, highlighting the effectiveness of increased repetitions achievable through robotic assistance.

In [6] they have introduced the use of various sensors, including EMGs and force sensors, in rehabilitation exoskeletons. Even so, it is important to recognize certain challenges including the complexity of the system, the potential discomfort of the patients, and considerations related to time consumption.

In the study of sensor-less rehabilitation [7], a master-slave configuration is presented. While the use of a reaction torque observer is notable, certain challenges persist, including the need for the presence of a therapist, maintaining non-relaxed shoulder positions, and limitations of mobility of the robot.

Following this, [8] introduces a bimanual rehabilitation robot with a reference torque profile (based on elbow angle), eliminating the constant need for a therapist. However, there are no means for relaxed shoulder position and only capable of flexion and extension of the lower arm. In contrast to that, our robot introduces unique feature of performing both Flexion & extension and Internal & External Rotation, while maintaining the shoulder in a relaxed upright position for optimal effectiveness. These innovations address significant gaps, offering a more efficient rehabilitation solution.

III. MATERIALS AND METHODS

The non-paretic and paretic arms are operated by a master robot and a slave robot. The target is facilitating bimanual movement while developing the arm strength to a healthy level (using the profile). The motor supplies a controlled resistance to the arm and the arm moves against it. Passive and assistive modes are used for non-paretic and paretic arms. Passive mode is a torque controller and assistive mode is a torque controller along with an assistance. The assistance is supplied by a virtual torsional spring based on the position difference between master and slave.

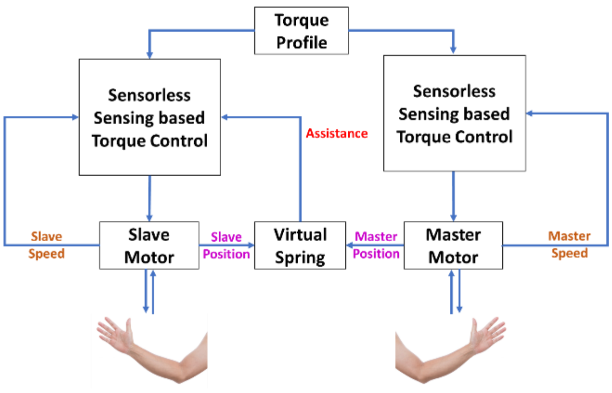

Fig. 1. System block diagram

The spring constant can be adjusted according to the patient condition.

Reaction Torque Observer is used to estimate the arm torque and Disturbance Observer is used for disturbance compensation. By those methods, we reduce measuring errors and complexity with less sensors and are able to increase the bandwidth of toque measurements as required. The outcomes are measurable as position and torque responses.

IV. Results and Discussion

The control system with above features has been simulated for a modeled system and the results are shown in Figure 2. The slave position is lower than the master position and the same happens with the torque produced. The resistance by the slave motor is reduced accordingly by the torque from a virtual spring to make the paretic arm move with the other.

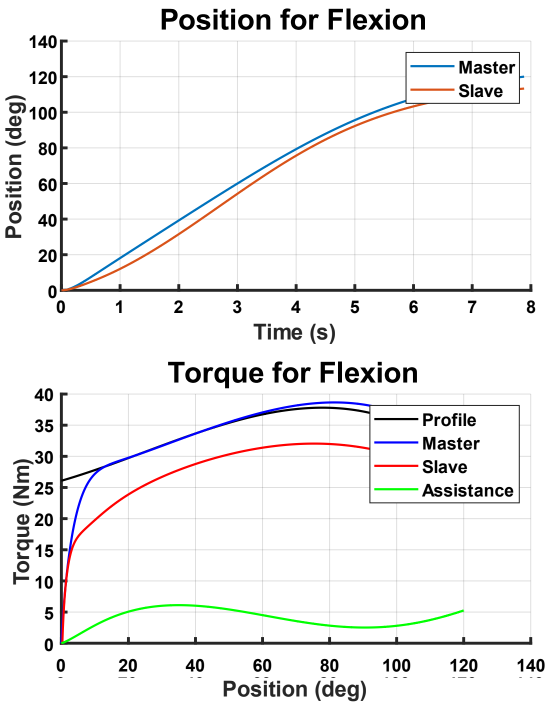

Fig. 2. Simulation results

The changing of the motor orientation is done by manually rotating the part on which the motor is mounted, by 90˚ as shown in Figure 3(b) and 3(c).

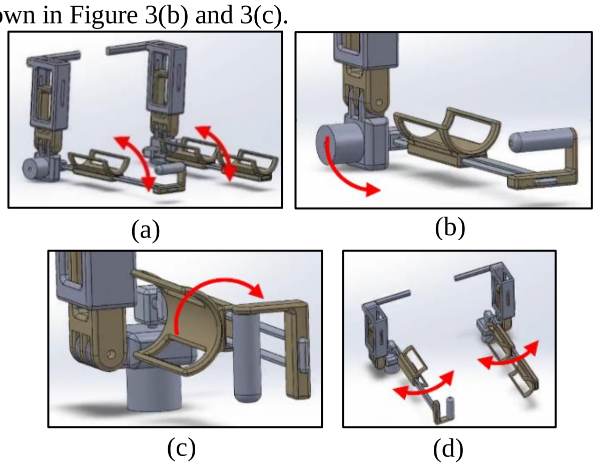

Fig. 3. Physical design

Figure 3 illustrates followings.

(a) Flexion and extension
(b) Rotation of motor-mounted part
(c) Rotation of forearm support
(d) Internal and external rotation

V. Conclusion

We are planning to develop a bimanual rehabilitation robot to perform exercises that reinstate the bimanual coordination of the human arms. The approach used is to give resistance to arm motion according to a healthy elbow torque profile. To assist the paretic arm to move with the healthy arm, a virtual torsional spring is modeled based on the lag of the paretic arm. By training with the robot, the bimanual coordination of the arms will be developed along with the strength of the paretic arm, to a healthy level. The results can be quantified, and the system parameters can be adjusted to give the optimal rehabilitation. For the maximum effectiveness and comfort of the patient, we provide the adjustment to keep the shoulder in a relaxed position. The robot will have the capability to do two exercises in perpendicular planes with 1 DOF control. Hence, this will provide a simple, mobile cost-effective, and adjustable solution for rehabilitation.

Acknowledgment

Authors gracefully acknowledge the University of Moratuwa in Sri Lanka, Asian Institute of Technology and Mahidol University in Thailand. This study was supported by a research grant from the National Broadcasting and Telecommunications Commission (Contract No. A64-1-(2)-006), Thailand.

References

[1] K. M. Iburg, "Global, regional, and national disability-adjusted lifeyears (dalys) for 315 diseases and injuries and healthy life expectancy (hale), 1990–2015: a systematic analysis for the global burden of disease study 2015," *Lancet*, vol. 388, no. 10053, pp. 1603–1658, 2016.

[2] G. Kwakkel, B. J. Kollen, and R. C. Wagenaar, "Therapy impact on functional recovery in stroke rehabilitation: a critical review of the literature," Physiotherapy, vol. 85, no. 7, pp. 377–391, 1999.

[3] G. Stucki, M. Stier-Jarmer, E. Grill, and J. Melvin, "Rationale and principles of early rehabilitation care after an acute injury or illness," *Disability and rehabilitation*, vol. 27, no. 7-8, pp. 353–359, 2005.

[4] P. S. Lum, D. J. Reinkensmeyer, and S. L. Lehman, 'Robotic assist devices for bimanual physical therapy: preliminary experiments', *IEEE Trans. Rehabil. Eng.*, vol. 1, no. 3, pp. 185–191, Sep. 1993, doi: 10.1109/86.279267.

[5] R. Gassert and V. Dietz, 'Rehabilitation robots for the treatment of sensorimotor deficits: a neurophysiological perspective', *J. NeuroEngineering Rehabil.*, vol. 15, no. 1, p. 46, Dec. 2018, doi: 10.1186/s12984-018-0383-x.

[6] S. Sirawattanakul and W. Sanngoen, 'Review of Upper Limb Exoskeleton for Rehabilitation and Assistive Application', *Int. J. Mech. Eng. Robot. Res.*, pp. 752–758, 2020, doi: 10.18178/ijmerr.9.5.752-758.

[7] P. A. D. Harischandra and A. M. H. S. Abeykoon, 'Upper-Limb Tele-Rehabilitation System with Force Sensorless Dynamic Gravity Compensation', *Int. J. Soc. Robot.*, vol. 11, no. 4, pp. 621–630, Aug. 2019, doi: 10.1007/s12369-019-00522-1.

[8] P. A. D. Harischandra and A. M. H. S. Abeykoon, 'Development of an upper limb master-slave robot for bimanual rehabilitation', in *2017 Moratuwa Engineering Research Conference (MERCon)*, Moratuwa: IEEE, May 2017, pp. 52–57. doi: 10.1109/MERCon.2017.7980455.