

# Development and Control of an Upper Extremity Robotic Exoskeleton for Rehabilitation

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## Abstract

Functional impairments of the Upper Extremity (UE) are common not only among the elderlies, but can also result from *cerebrovascular accident* (CVA), *amyotrophic lateral sclerosis* (ALS) and *spinal cord injury* (SCI) in any individual. Citing the constant growth of UE Dysfunctions and required prolonged rehabilitation, robot-assisted therapy has already been contributing to restoring UE functions. Though, extensive research has been conducted on rehabilitation robotics, limitations still exist compared to required degrees of freedom and range of motion for effective UE rehabilitation. In this research, we have developed a 3-DOF robotic exoskeleton to provide rehabilitation therapy to the shoulder and elbow joints. The exoskeleton was designed for typical adult; provision includes for link-length adjustment to accommodate a wide range of users. The robot arm will be attached to the lateral side of human UE to provide shoulder joint vertical and horizontal flexion/extension and elbow flexion/extension motion. Modified Denavit-Hartenberg notions were used to develop the kinematic model and Newton-Euler formulation was used for the dynamic modeling of the developed robot. Control has been implemented on LABVIEW environment. Experimental results revealed that this robot can be effectively maneuvered to follow the desired trajectories (shoulder and elbow joint motion) to provide passive rehabilitation therapies.

## Keywords

Kinematic and dynamic modeling, exoskeleton robot, rehabilitation, trajectory tracking, upper extremity impairment

## Biographies

**Tanvir Ahmed** is a graduate student in the Biomedical Engineering Department, University of Wisconsin-Milwaukee. Currently he is pursuing his MS (leading to PhD) and working at the BioRobotics lab, UWM as a research assistant under supervision of Dr. Rahman. He received his BSc. Engineering (mechanical) degree from Khulna University of Engineering & Technology, Bangladesh in 2014. His expertise includes design, development and control of wearable robots. He is interested in developing novel robotic systems for providing therapy and assistance to individuals with physical disabilities.

**Ivan Rulik** is a senior Electrical and Biomedical Engineering international student from Universidad de los Andes, Colombia, and will get his degree in 2020. He is currently a Research Assistant in the Mechanical Engineering Department at the University of Wisconsin-Milwaukee, working in the BioRobotics lab under the help of Dr. Rahman. He brings expertise in programming using LabView®, designing control systems and analysis of physiological signals. His research interests include robotics, medicine, electromagnetism, and mechanical engineering.

**Asif Al Zubayer Swapnil** is a graduate student in the Mechanical Engineering Department of the University of Wisconsin-Milwaukee. Currently he is working for his MS (leading to PhD) at the BioRobotics lab under supervision of Dr. Rahman. He received his BSc. Engineering (mechanical) degree from Khulna University of Engineering & Technology, Bangladesh in 2014. He worked as an industrial and mechatronic system designer in product design industries for 4 years. His research interests include mechatronics and robotic systems for rehabilitation and assistance persons with physical disabilities.

**Md Assad-Uz-Zaman** (Ph.D student) at Bio-Robotics Lab, Mechanical Engineering Department, University of Wisconsin-Milwaukee, Milwaukee, WI USA. He received BSc Engineering (mechanical) from KUET, Khulna Bangladesh in 2013., a Master of Science (Mechanical Eng.) degree from University of Wisconsin-Milwaukee, USA in 2017. His research interests are in Portable rehabilitation device, Artificial Intelligence and Robot motion planning.

**Md Rasedul Islam** is currently a PhD candidate and Distinguished Dissertation Fellow in Mechanical Engineering department in the University of Wisconsin – Milwaukee (UWM), USA. Mr Islam has been researching in wearable robotics intended to be used in rehabilitation of human upper limb of post-stroke patients. In addition, He has been working as a research assistant at Bio-Robotics lab here in UWM since August 2015. Mr Islam has been awarded a prestigious Distinguished Graduate Student Fellowship by UWM graduate school in 2017. Earlier, he has done his B.S in Mechanical Engineering from Khulna University of Engineering & Technology (KUET), Khulna, Bangladesh, in 2012. Soon after his B.S, he has joined as Lecturer in Mechanical Engineering in KUET.

**Mohammad Habib Rahman** is with the Mechanical and Biomedical Engineering Department, University of Wisconsin-Milwaukee, WI, USA. As Director of the BioRobotics Lab at the University of Wisconsin-Milwaukee, he brings the resources and expertise of an interdisciplinary R&D team. For more than 15 years he has been researching bio-mechatronics/bio-robotics with emphasis on the design, development and control of wearable robots to rehabilitate and assist elderly and physically disabled individuals who have lost their upper-limb function or motion due to stroke, cardiovascular disease, trauma, sports injuries, occupational injuries, and spinal cord injuries. He received a BSc Engineering (mechanical) degree from Khulna University of Engineering & Technology, Bangladesh in 2001, a Master of Engineering (bio-robotics) degree from Saga University, Japan in 2005 and a PhD in Engineering (bio-robotics) from École de technologie supérieure (ETS), Université du Québec, Canada in 2012. He worked as a postdoctoral research fellow in the School of Physical & Occupational Therapy, McGill University (2012-2014). His research interests are in bio-robotics, exoskeleton robot, intelligent system and control, mobile robotics, nonlinear control, control using biological signal such as electromyogram signals.