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Design and Development of Soft Exoskeleton for Rehabilitation and Assistive Robotics

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Abstract

In the field of rehabilitation and support, where it is essential to ensure safe interactions between humans and technology, soft actuators and robotic devices are causing a stir. Soft actuators and robotic devices have several advantages over their stiff counterparts, such as safer interactions, the capacity to execute intricate movements, simpler construction, and environmental adaptation. Over the past few decades, a lot of effort has gone into creating soft rehabilitation and assistive devices aimed at enhancing medical treatments and improving quality of life. Actuators and grippers are examples of soft robotic systems that have been used in many commercial applications over the past ten years. Scientific interest in activities involving close human-robot contact has increased, especially in the field of human exoskeletons, as a result of the rising need to incorporate robotic mechanisms into devices that work alongside people. Patients with neurological disorders and movement issues are usually helped and rehabilitated by these exoskeletons. In this regard, a soft robotic hand exoskeleton system with advanced air-pressurized soft actuators created with additive manufacturing methods has been designed and developed.

Keywords: Robotic Exoskeleton; Rehabilitation; Assistance.

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Introduction

Robotic devices and soft actuators can be viewed as soft systems that use extremely flexible materials that replicate the kPa to MPa elastic characteristics of soft biological tissues and human organs. Because of their large degrees of freedom (DoF) and flexible structures, these systems are highly adaptive, able to perform a wide range of natural and fluid movements, and generally more resilient

(Gopura & Kiguchi, 2009). Usually, low-temperature methods are employed to create the soft materials used in these actuators and devices, which simplifies production and lowers costs. Furthermore, its viscoelastic properties smooth out sudden motions and forces by absorbing impact energy and reducing oscillations. Growing interest in creating soft robotic devices for help and rehabilitation has been spurred by these unique soft properties, particularly in situations where maintaining safety during human-machine interactions is essential (Iqbal et al., 2014).

While it's clear that we all want rehabilitation and assistive devices to be soft, cost-effective, safe, and user-friendly, the reality is that the best options available today still depend on a mix of rigid actuators, links, and joints to create various movements (Pons, 2010; Nycz et al., 2015). Even though rigid actuators are precise, they often come with a limited range of motion due to their degrees of freedom (DoF). This limitation makes them less adaptable to the diverse needs of different users. For instance, to achieve a twisting motion, you might need several different electric motors working together (Huo et al., 20014). Numerous advantages result from this, such as cost reductions, simplicity of manufacturing, lightweight design, and adaptability. Therefore, by utilizing the almost infinite DoF that soft actuators provide, assistive devices and soft rehabilitation can execute a wide range of complex actions. However, we must make sure that the critical technologies of sensing, actuation, control, and power supply are smoothly integrated and working together if we want these soft actuators and robotic devices to really shine in rehabilitation and support (Rocon et al., 2007).

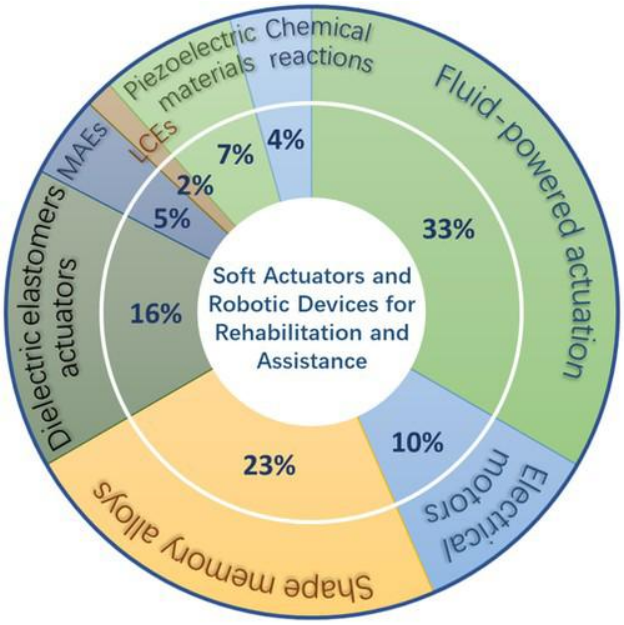

Fig. 1: An Overview of the Most Recent Advancements in Robotic Devices and Soft Actuators for Aid and Rehabilitation.

Methodology

We discovered 65 pieces of literature about soft robotic hand exoskeletons. But for our systematic review, we only chose forty-five devices. This was due to the fact that certain designs were utilized for different reasons and appeared in many articles. For example, the Exo-Glove Poly and Exo-Poly PM, which have a similar design approach, were introduced by the SNU research group. An additional illustration is the NUS research team, who first created the MRC glove for fMRI in 2015 and then announced in 2016 that stroke patients could use it. It is important to note that this study did not include hand exoskeletons with rigid actuation or rigid wearable links.

Additionally, since prosthetic and anthropomorphic hands include a gripper that may be replaced or fastened to a garment or stump, we excluded them.

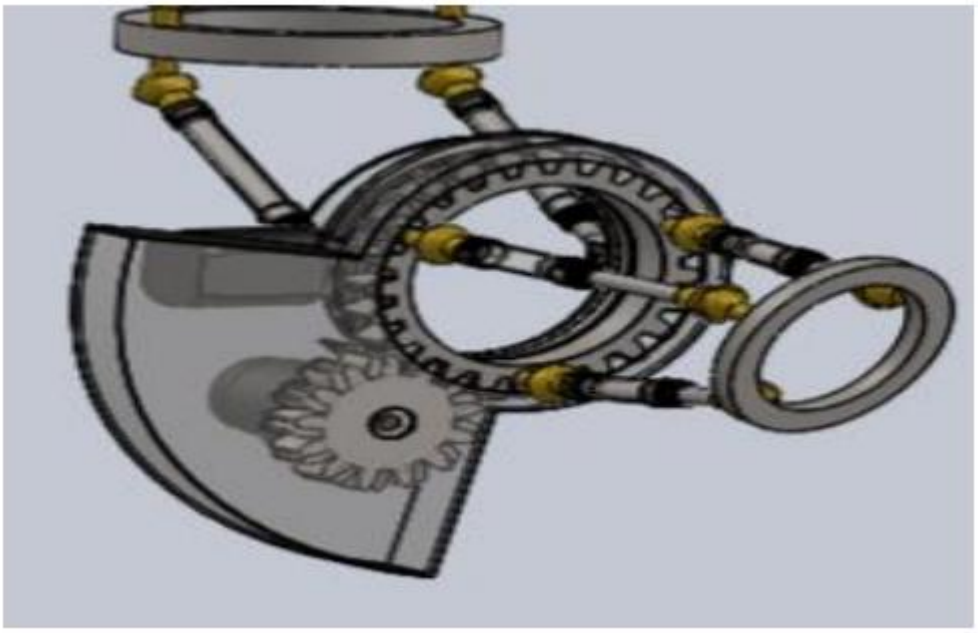

Fig. 2: Four d-o-f Hybrid Exoskeleton Robot

It examined the hand exoskeleton's mechanical and electrical components, emphasizing at least three crucial features: actuation, active DOFs, finger movement, output force, range of motion (ROM), weight, and general usefulness.

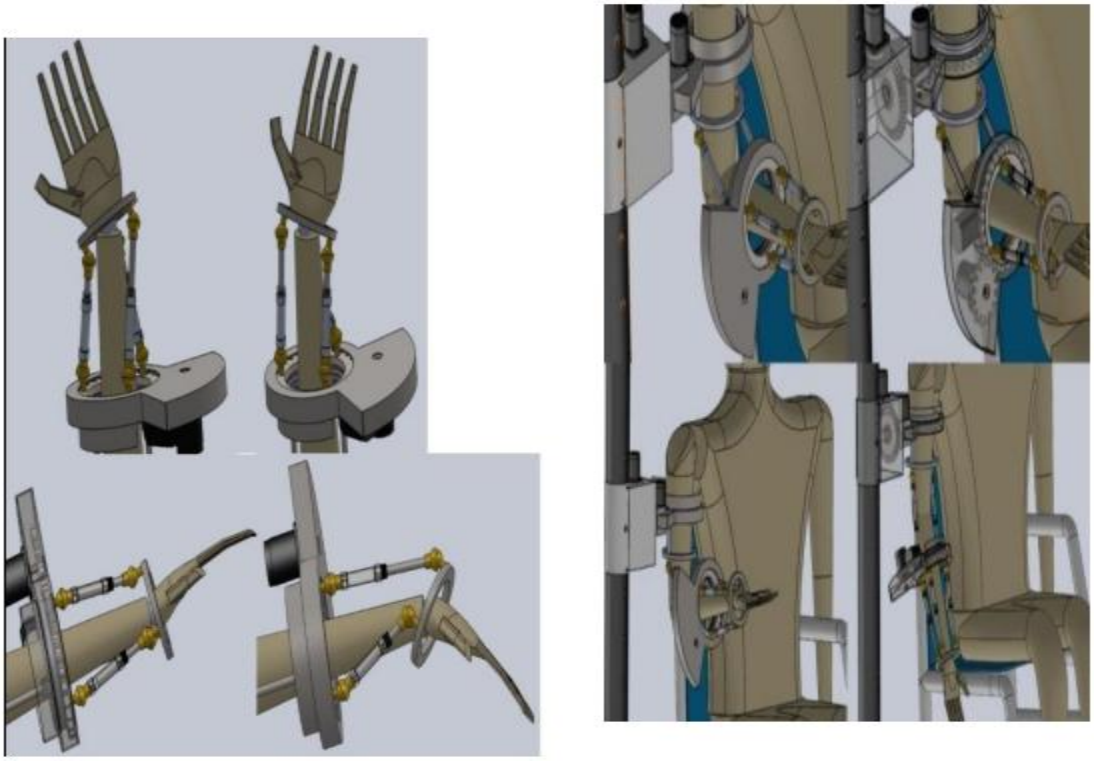

Fig. 3: (a) Wrist Motions(b) Elbow Motions

Finally, even though hand exoskeletons and prosthetic and anthropomorphic hands serve comparable purposes, our research focused on exoskeletons made primarily to help and rehabilitate people with medical disorders including stroke and muscular abnormalities (Tsagarakis & Caldwell, 2003; Yap et al., 2015).

Results and Discussion

The three graphs show that when the displacement near the top platform's center (o2) changes smoothly (the moving platform changes linearly over time from 300 to -50), the displacements of the legs r1, r2, and r3 also change smoothly over a wide range during the inverse displacement analysis of wrist ulnar deviation to wrist radial deviation. This suggests that the upper PM exhibits strong kinematic characteristics during the wrist ulnar to radial deviation motion (Lu et al. 2015).

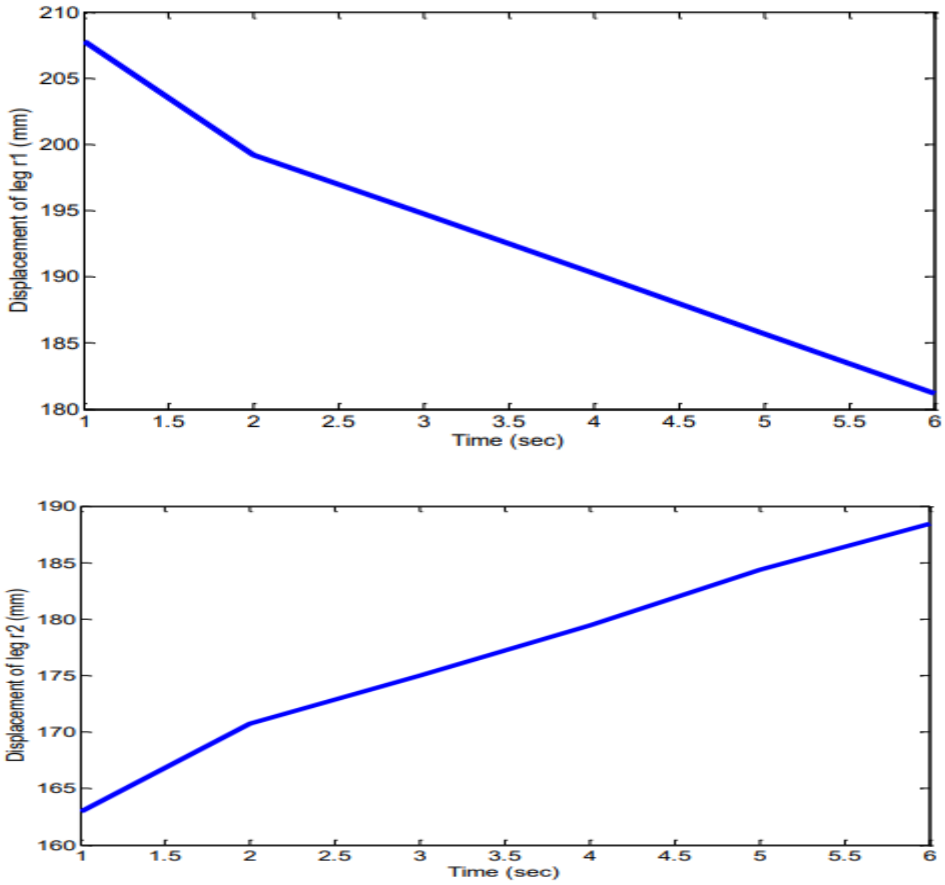

Fig. 4: Displacement Graph

According to the kinematic results, the suggested robot exhibits remarkable kinematic properties for a range of actions, such as elbow supination, elbow pronation, elbow flexion, elbow extension, wrist radial deviation, wrist ulnar deviation, and wrist extension. This indicates that two wrist and two elbow motions are easily handled by the robot. With this hybrid robot, rehabilitation therapy becomes a viable option, allowing patients to regain strength in their upper limbs. The workspace for all these motions has been plotted using the MATLAB PDE toolbox.

Conclusion

In this overview, we examine several soft robotic hand exoskeletons in greater detail, assessing their benefits and drawbacks as well as the technological developments in this area throughout the previous ten years. We discuss the basic characteristics and design criteria of 45 distinct soft wearable exoskeletons. The general patterns and actuation mechanics of these soft robotic hands are highlighted in this comprehensive review. Using force sensors and a motion capture system, we assessed the devices' range of motion and force. The findings demonstrated that they provide sufficient force and a respectable range of motion to manage a variety of jobs. In order to facilitate finger

actuation with increased stiffness, better material stability, and a more aesthetically pleasing design, plans are underway to improve the force output.

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