Teleoperation Control of Multi-Joint Systems: Piloted Potentiometer Exoskeleton Arm

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EXPO

Abstract

Control of multi-joint systems such as robotic arms using a gamepad-like interface is tedious and non-intuitive. Gamepad-like interfaces are complicated to use for controlling multiple joints simultaneously. This research presents the development of a passive user-piloted exoskeleton arm that strap onto the user's upper body. Potentiometers are integrated at each joint to accurately track angular movements. The collected data is then mapped and teleoperated to an identical motor-joint system through radio signals, enabling the human pilot to control the system with great precision at a distance up to 100 meters. By augmenting remote control capabilities and improving the pilot experience, this project holds promise for expanding the dexterity and task adaptability of remote-controlled joint robots. The integration of potentiometer-based tracking and teleoperation offers a novel approach to achieving unprecedented precision and maneuverability in remote-controlled robotic joint systems. Such devices hold promising applications in teleoperation in nuclear reactors, search-and-rescue, and space operations.

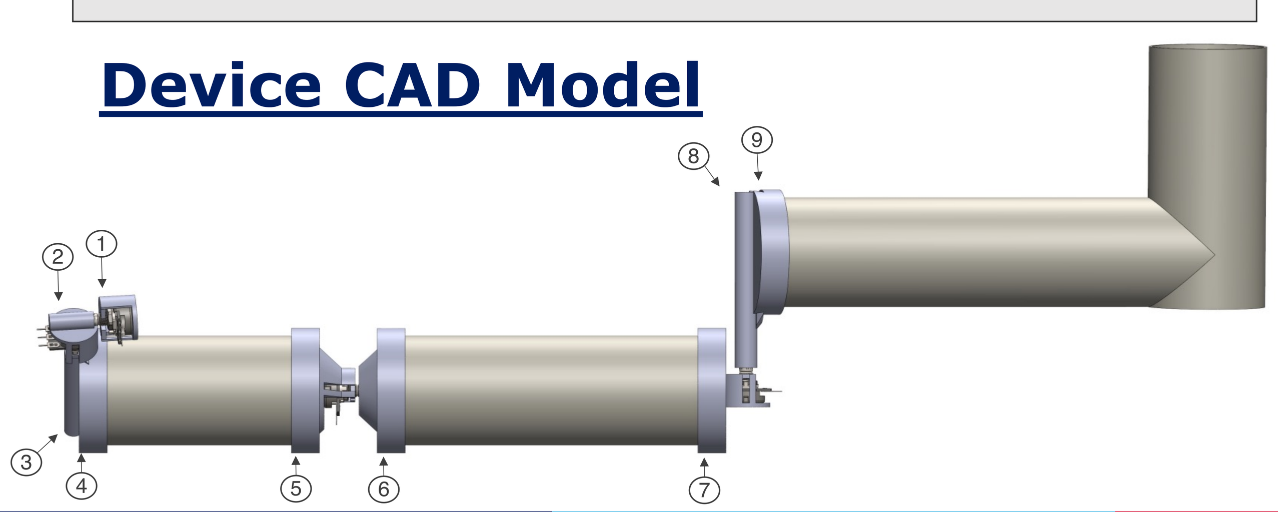
Introduction

In the advent of sophisticated mechanical systems, such as robot arms equipped with multiple joints, a level of complexity is introduced in control that necessitates a reconsideration of how human operators interface with these machines. The conventional methods of joystick-based or software-guided controls are limited in their capacity to offer the nuanced, intuitive control necessary for intricate tasks. These limitations underscore the need for innovative approaches that bridge the gap between human intention and mechanical action in a more natural manner.

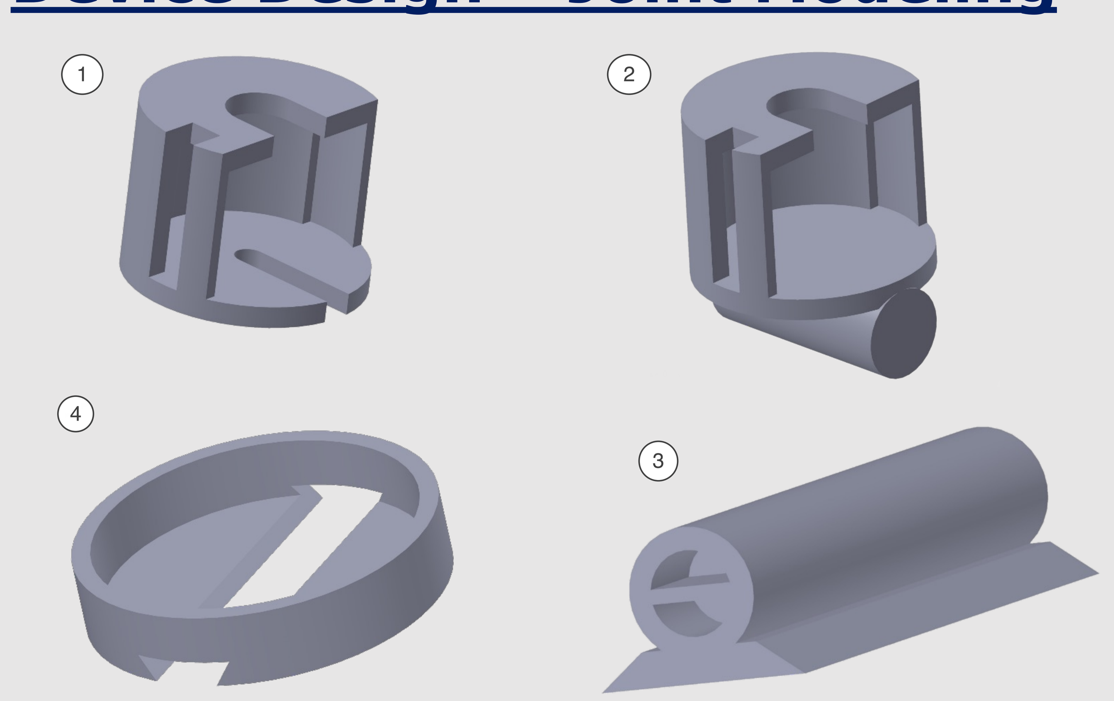
Addressing this challenge, the current project introduces a novel approach to remote control systems by developing a mobile user-controlled exoskeleton arm. This system leverages potentiometers integrated at each joint of the exoskeleton to capture precise angular movements. These movements are accurately tracked and then teleoperated to an identical joint system, mirroring the operator's motions with high fidelity. This method represents a significant leap forward in remote control technology, moving beyond traditional interfaces to a more direct and intuitive form of human-machine interaction.

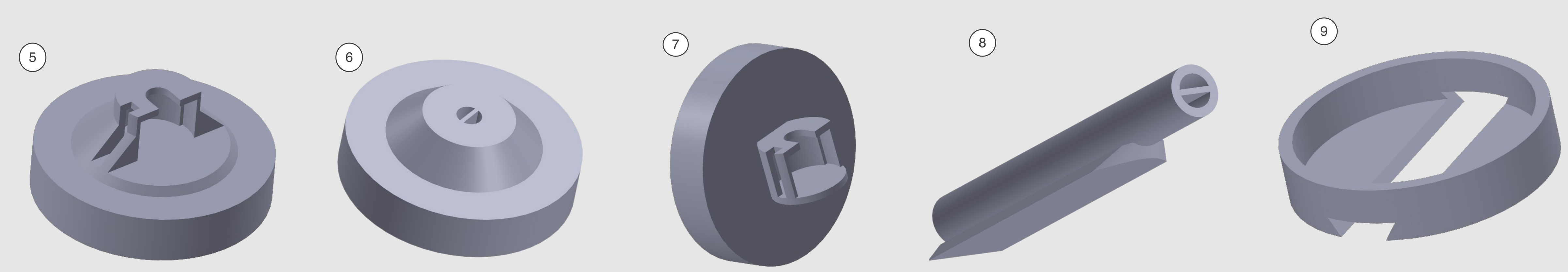
The integration of potentiometer-based tracking within this exoskeleton arm enables the precise mapping of human movements to a robotic counterpart, effectively translating the operator's intent into mechanical action with unprecedented intuitive control.

Device CAD Model



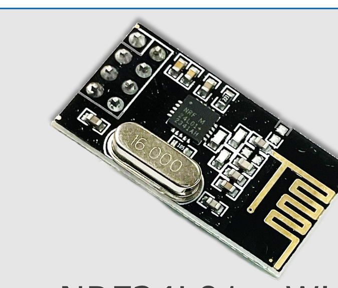
Device Design – Joint Modeling

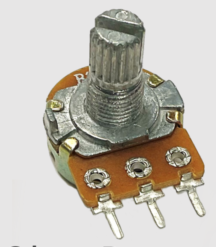




Components


Arduino Uno


NRF24L01+ Wireless Transceiver


10k Ohm Potentiometer


Tactical Backpack


3-D Printing PLA Filament


1.5″ Carboard Tubing


2″ Carboard Tubing

Device Design - Adjustability

One of the primary considerations in the design process was ensuring that the exoskeleton arm could comfortably support users of different sizes. To achieve this, the team focused on creating a design that was adjustable and customizable:

The device needed to securely attach to the user's upper body while maintaining comfort. To address this, the team employed a utility backpack. The backpack provided a familiar and comfortable method of attachment for users. This approach also allows for macro upper body size adjustments to fit different users.

The device also has an integrated telescoping length handle. This feature allowed users to customize the length, positioning and rotation of the handle according to their comfort and reach. This allows portion of the device held by the user to extend or retract as needed. This telescoping feature caters to users with varying arm lengths or preferences for operating distances.

Device Design – Durability

In early stage prototypes the 3D printed PLA joints were experiencing critical failure due to the stresses applied to each joint. The team redesigned several variations of joints 1, 5, and 8, but the distribution of stresses were too great. To assist in solving this problem, a surface finish of superglue was applied to each joint. Superglue can penetrate the microscopic gaps and imperfections on the surface of 3D printed parts, reinforcing their structural integrity and making them more resilient to the stress and strains encountered during operation.

Given that cardboard has a significant loss of strength upon exposure to water and sweat, three coatings were evaluated to enhance the durability of cardboard and bolster its resistance to moisture. The coatings were a commercial waterproofing fabric spray, a painted rubber sealant, and a wrap of duct tape. First, 2.5in samples of tubing were wrapped with a moistened paper towel, then their structural integrity was assessed either through a compression test—where increasing weights were applied until noticeable deformation occurred—or by monitoring moisture penetration using dry potting soil and a sensor to detect water seepage through the coating. Among the various coatings examined, duct tape significantly outperformed others in enhancing the cardboard's crush resistance. Meanwhile, in the moisture permeability assessment, the three innovative coatings demonstrated similar levels of effectiveness.

Conclusion

This innovative approach marks a significant leap forward in the field of robotic control, particularly for multi-joint systems. By leveraging the natural movements of the human body and translating them into precise control for robotic arms, this technology effectively bridges the gap between human intention and robotic action. This not only enhances the precision and maneuverability of these systems but also transforms the user experience, making the operation of complex robotic systems more intuitive and significantly less burdensome for the operator.

The implications of such a technological advancement are profound. In environments where the risk to human operators is too great, such as inside nuclear reactors, amid search-and-rescue operations, or within the harsh confines of space, the ability to deploy robotic systems that can be controlled with such precision and intuitiveness can significantly enhance operational effectiveness. These robots can undertake tasks that require a high degree of dexterity and adaptability, tasks that traditional remote-controlled or autonomous robots may struggle to perform efficiently.

Acknowledgements

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