Simulation and Control of an SO-101 Robotic Arm for Assistive Daily Living Tasks

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Abstract

Assistive robotic systems have the potential to improve independence and quality of life for individuals with mobility impairments by helping them perform everyday tasks. In this article, I investigate the feasibility of using low-cost robotic arms to assist wheelchair users with object manipulation and retrieval. I first assembled and calibrated a physical SO-101 robotic arm system consisting of a leader and follower arm, each with six degrees of freedom. The follower arm was configured to replicate the leader's movements through teleoperation. I then implemented the SO-101 arm in the MuJoCo physics simulation environment and trained it to perform object manipulation tasks, including reaching, grasping, and lifting objects. Building on this work, I developed a simulated assistive wheelchair equipped with two SO-101 robotic arms mounted beside the armrests, providing a framework for exploring coordinated robotic assistance. The proposed system could eventually help wheelchair users retrieve dropped objects, pick up drinking bottles, handle medication containers, and access everyday items without caregiver assistance. This article establishes an initial framework for integrating affordable robotic manipulators with mobility devices, with future work focusing on coordinated dual-arm manipulation, autonomous object detection, and real-world implementation.

Introduction

Assistive robotics has emerged as a promising approach to improving independence and quality of life for individuals with physical disabilities. According to the World Health Organization (WHO), approximately 80 million people worldwide require wheelchairs for mobility assistance [6]. Although wheelchairs enable individuals with mobility impairments to navigate their environments, they do not necessarily address difficulties with manipulating objects, particularly for people who also experience limited upper-limb function. Everyday activities such as retrieving dropped items, reaching for objects on shelves, handling food and beverages, and accessing personal belongings can require assistance from caregivers. Integrating robotic manipulators directly into wheelchairs could provide individuals with greater control over their surroundings and reduce their dependence on others.

Wheelchair-mounted robotic arms have been investigated as a potential solution to these challenges. For example, the Kinova JACO robotic arm has been developed to assist individuals with upper-limb impairments in performing activities of daily living. Research involving users of the JACO arm has demonstrated its potential to support independent activities, including drinking, retrieving objects, and interacting with the surrounding environment [4]. However, significant challenges remain in making assistive robotic systems widely accessible. A systematic review by Rahman et al. identified several limitations of existing wheelchair-mounted robotic arms, including high costs, restricted workspaces, limited payload capacity, insufficient gripper dexterity, and challenges related to safety and control [3]. These limitations motivate the development of affordable, adaptable robotic systems that can be tailored to the needs of individual users.

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One promising approach involves using open-source robotic hardware combined with simulation-based training. The SO-101 robotic arm, developed as part of the Hugging Face LeRobot ecosystem, provides an accessible platform for exploring robotic manipulation. Its six-actuator configuration enables controlled movement of multiple joints and a gripper, while its leader-follower architecture allows one arm to reproduce movements performed using another [2]. Such teleoperation systems provide an intuitive way to control robotic manipulators and potentially collect demonstrations for training autonomous behaviors. Previous research has highlighted the importance of teleoperation in combining human decision-making with robotic control, particularly for manipulation tasks that remain difficult to automate completely [1]. For assistive applications, combining teleoperation with autonomous manipulation could eventually allow users to select objects or initiate tasks while the robot performs the necessary movements.

Physics-based simulation environments provide an additional opportunity to develop and evaluate robotic control strategies before implementing them on physical hardware. MuJoCo (Multi-Joint Dynamics with Contact) is a physics engine designed for simulating articulated robotic systems, including joint dynamics, contact forces, and interactions between objects [5]. By representing robotic arms and their surroundings in a virtual environment, MuJoCo enables experimentation with object reaching, grasping, and manipulation without requiring repeated physical trials. Simulation is particularly useful for assistive robotics, where interactions between moving robotic arms, wheelchairs, and human users introduce important mechanical and safety considerations.

In this article, I explore the development of a low-cost assistive robotic system based on the SO-101 robotic arm. I first assembled and calibrated a physical leader-follower SO-101 system to investigate robotic motion control and teleoperation. I then implemented the SO-101 arm in MuJoCo and trained it to perform basic object manipulation tasks, including reaching, grasping, and lifting objects. Building on these developments, I designed a simulated wheelchair equipped with two SO-101 robotic arms positioned beside the armrests. This dual-arm configuration is intended to expand the accessible workspace around a wheelchair user and provide a foundation for tasks such as retrieving dropped objects, handling personal belongings, and accessing food, beverages, or medication containers. The objective of this article is to demonstrate the initial feasibility of combining affordable robotic hardware with simulation-based manipulation and wheelchair integration, while establishing a foundation for future work on autonomous assistance, coordinated dual-arm control, and physical deployment.

Methods



(a) Leader

(b) Follower

Figure 1: SO-101 robotic arm: leader and follower configurations.

SO-101 Robotic Arm Assembly and Calibration

I constructed a physical robotic manipulation system consisting of two SO-101 robotic arms, following the open-source design provided by Hugging Face's LeRobot project [2]. The system consists of a leader arm and a follower arm, as shown in Figure 1. The structural components were 3D printed and assembled using screws and six servo motors per arm, enabling articulated movement and gripper control.

The leader and follower arms were configured with different motor gear ratios to accommodate their respective functions. The leader arm used gear ratios of 1:191 for the base and elbow joints and 1:147 for the wrist and gripper, allowing relatively smooth manual manipulation. The follower arm used higher gear ratios of 1:345 to provide greater torque and stability during object manipulation. The leader arm operated at 5 V, while the follower arm operated at 12 V.

Following assembly, each servo motor was assigned a unique identification number and connected to the control system. I calibrated the arms using the `lerobot-calibrate` command, moving the joints through their allowable ranges of motion to establish their positional limits and reference configurations. The arms were then synchronized using a leader-follower teleoperation setup, in which manually moving the leader arm generated corresponding movements in the follower arm. This setup provided a physical platform for investigating robotic control and manipulation.

Object Manipulation Training in MuJoCo

To investigate object manipulation before integrating the robotic arms into a wheelchair, I implemented a simulated SO-101 robotic arm using MuJoCo, a physics-based simulation engine capable of modeling articulated bodies, joint dynamics, and contact interactions [5]. The simulation environment contained a robotic arm and a cube-shaped object that served as the target for manipulation tasks.

I divided the manipulation training into two stages of increasing complexity. In the first stage, the objective was to move the robotic arm's gripper toward the cube. This reaching task required controlling the arm's joint movements to position the end effector near the target object without requiring physical contact or grasping.

In the second stage, the task was extended to grasping and lifting the cube. The robotic arm was trained to approach the object, position its gripper around it, close the gripper, and lift the object from its initial position. Unlike the reaching task, this stage required the simulated robot to interact physically with the cube through contact forces and coordinated joint movements. These tasks provided a foundation for developing manipulation behaviors that could eventually be used in assistive applications.

Simulation of a Dual-Arm Assistive Wheelchair

Building on the single-arm manipulation environment, I developed a wheelchair model in MuJoCo and integrated two simulated SO-101 robotic arms into its structure. The arms were positioned on opposite sides of the wheelchair, adjacent to the armrests, providing access to objects located to the left and right of the user.

The dual-arm configuration was designed to explore how robotic manipulators could be incorporated into mobility devices to assist individuals with limited upper-limb function. In a potential assistive application, the robotic arms could retrieve objects from nearby surfaces, pick up items dropped on the ground, and assist with handling everyday objects such as water bottles, medication containers, and personal belongings.

The wheelchair and robotic arms were represented within the same physics simulation environment, establishing a virtual platform for investigating wheelchair-mounted manipulation. The completed model provides a foundation for future investigations of arm reachability, collision avoidance, coordinated dual-arm manipulation, and autonomous object retrieval. At this stage,

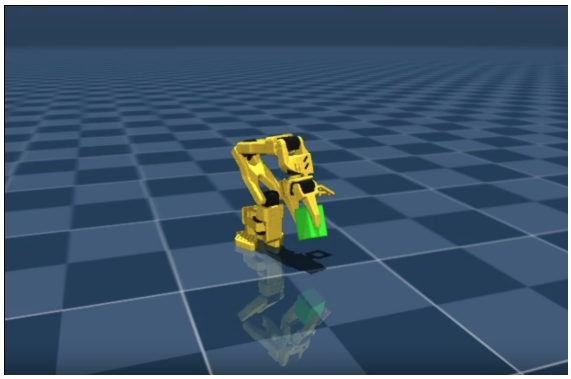


Figure 2: SO-101 robotic arm performing object manipulation in MuJoCo.

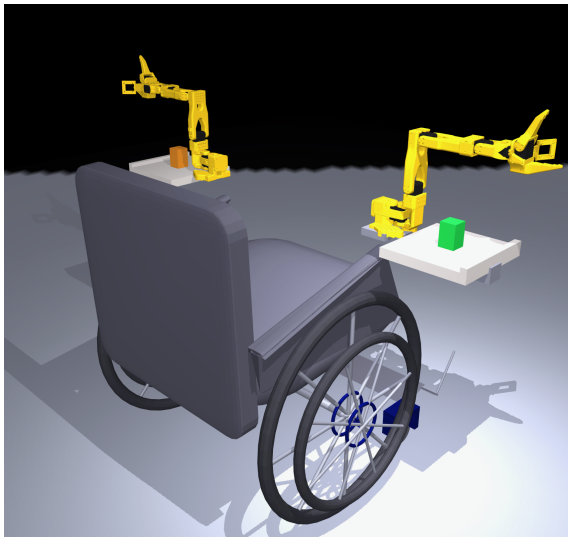


Figure 3: Simulated wheelchair equipped with two SO-101 robotic arms.

the wheelchair integration was implemented in simulation rather than as a physical wheelchair prototype.

Results

The physical assembly and calibration of the SO-101 leader-follower system enabled synchronized movement between the two robotic arms. During teleoperation, the follower arm reproduced the movements of the manually controlled leader arm, with a reported median angular difference of 0.31°. This demonstrated the ability of the assembled system to transfer joint movements between the two arms.

In the MuJoCo simulation environment, I successfully implemented the SO-101 robotic arm and trained it to perform basic object manipulation tasks. During the initial reaching task, the robotic arm learned to position its gripper near a target cube. The task was subsequently extended to grasping and lifting, requiring the gripper to establish contact with the cube and move it upward. Figure 2 illustrates the simulated SO-101 arm interacting with the target object. These results demonstrate the feasibility of performing fundamental manipulation tasks in a physics-based simulation environment, providing an initial foundation for more complex assistive behaviors.

Dual-Arm Wheelchair Simulation

Following the single-arm manipulation experiments, I successfully developed a simulated wheelchair equipped with two SO-101 robotic arms using MuJoCo. As shown in Figure 3, the arms were positioned on opposite sides of the wheelchair near the armrests, allowing them to access different regions surrounding the user. The simulation incorporated both robotic manipulators and the wheelchair into a single virtual environment.

The completed configuration demonstrates the feasibility of integrating two robotic manipulators into a wheelchair simulation. The arrangement provides a potential platform for assistive tasks such as retrieving objects from nearby surfaces, accessing personal belongings, and handling everyday items. However, while object manipulation was demonstrated using the individual simulated robotic arm, autonomous retrieval and coordinated dual-arm manipulation were not yet evaluated in the wheelchair configuration. The resulting simulation therefore serves as an initial prototype for investigating these capabilities in future work.

Conclusion

In this article, I explored the development of a low-cost robotic assistive system designed to improve independence for individuals with mobility impairments. I successfully assembled and calibrated a physical SO-101 leader-follower robotic arm system, demonstrating synchronized movement between the two manipulators. I subsequently implemented the SO-101 arm in the MuJoCo simulation environment and trained it to perform basic object manipulation tasks, including reaching, grasping, and lifting a cube. Building on these results, I developed a simulated wheelchair equipped with two SO-101 robotic arms mounted beside the armrests. Together, these developments demonstrate an initial approach toward integrating affordable robotic manipulators with mobility devices for assistive applications.

Despite these accomplishments, several limitations remain. Although object manipulation was demonstrated in simulation, the wheelchair-mounted dual-arm system has not yet been evaluated for autonomous task execution or coordinated manipulation. Furthermore, the physical robotic arms have not been integrated into an actual wheelchair, and their performance in real-world environments remains untested. Future work will focus on implementing computer vision algorithms for object detection and localization, developing autonomous control strategies for retrieving objects, and enabling coordinated movements between the two arms. Additional improvements could include voice-command interfaces and obstacle avoidance to make the system more accessible and safer for users with limited mobility.

Ultimately, the goal of this project is to develop an affordable wheelchair-mounted robotic system capable of assisting with everyday activities such as retrieving dropped objects, handling food and beverages, and accessing personal belongings. By combining open-source robotic hardware with simulation-based training, this article establishes a foundation for developing practical assistive technologies that could increase independence and reduce reliance on caregivers for individuals with physical disabilities.

References

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